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MYSTERIES OF THE ABYSS

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THE MISSIONS TO MAP THE ENTIRE OCEAN FLOOR

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Why Michael Mosley takes a cold shower every day

Education
How to change careers successfully

The tide is turning

When it comes to ocean-bound plastic pollution, enough is enough. Step forward the unique C60 #tide. A superlative dive watch with a neon-like sapphire dial and chronometer certified movement, it delivers power, accuracy and toughness in equal measure. But that's only half the story. Thanks to our partnership with social enterprise, #tide, the watch's case-back inserts and strap are made from 100% recycled ocean plastic (though you can also choose a marine-grade steel bracelet). Which makes for a healthier ocean. And a watch you'll take pride in wearing.

You can read more about the C60 #tide in the new issue of Loupe, our complimentary watch magazine. Sign up for yours at christopherward.com

christopherward.com

Christopher Ward

Ingeniously English.
Unsurprisingly Swiss.

FROM THE EDITOR

The deep sea is an alien place. It seems that almost every trip to the ocean floor returns with the discovery of a new creature, structure or process that baffles scientists. That's because, until now, it's been too challenging to catalogue everything that's down there. The extreme pressure means we're limited to brief visits, and with 71 per cent of the Earth's surface covered in salt water, there's a lot of area to cover.

It seems that might all be about to change. A cocktail of new missions and state-of-the-art technology will enable us to explore the ocean like never before. Robotic explorers will chart the ocean floors and its inhabitants, while research tools like environmental DNA will let us monitor biodiversity in totally unprecedented ways. But it's a race against the clock. Just as the climate crisis disturbs ecosystems above ground, it's likely to be damaging those beneath the waves too. Plus, the planet's demand for rare-earth metals and minerals used in modern tech will drive some countries to seek them at the bottom of the ocean, causing irreversible damage. Find out what we might learn in this new, fraught age of oceanic exploration on p52.

If you enjoy this issue, you should check out our podcast *Instant Genius,* available on your app of choice. Each episode serves up a mini masterclass on a different subject. Coming up, we're speaking to Dr Katy Munro about migraines, Lee McIntyre about the rise of science denial, and Fyodor Urnov about the potential of gene editing. Come and find us!

Daniel Bennett, Editor

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CONTRIBUTORS

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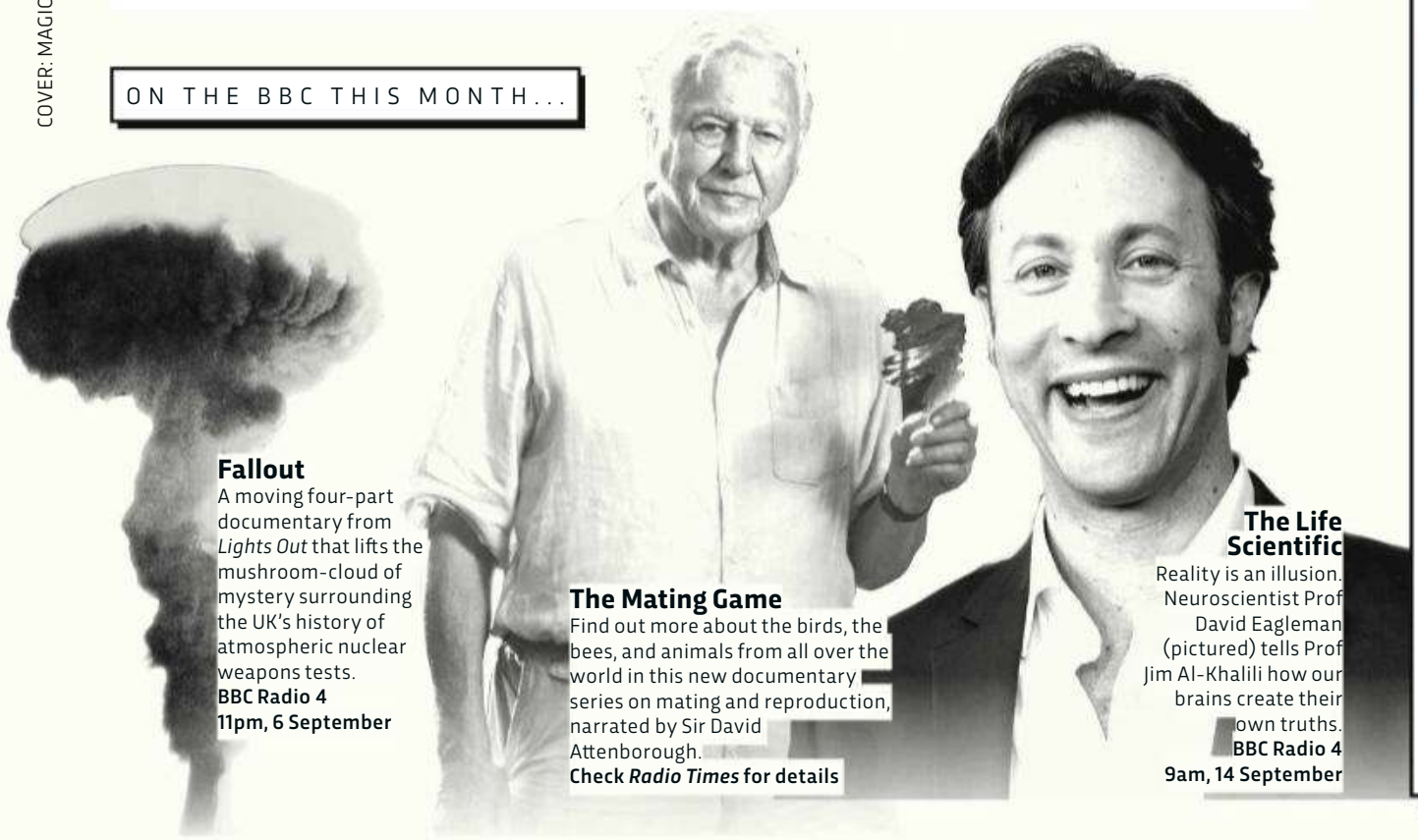

Fallout
A moving four-part documentary from *Lights Out* that lifts the mushroom-cloud of mystery surrounding the UK's history of atmospheric nuclear weapons tests.
BBC Radio 4
11pm, 6 September

The Mating Game
Find out more about the birds, the bees, and animals from all over the world in this new documentary series on mating and reproduction, narrated by Sir David Attenborough.
Check *Radio Times* for details

The Life Scientific
Reality is an illusion. Neuroscientist Prof David Eagleman (pictured) tells Prof Jim Al-Khalili how our brains create their own truths.
BBC Radio 4
9am, 14 September

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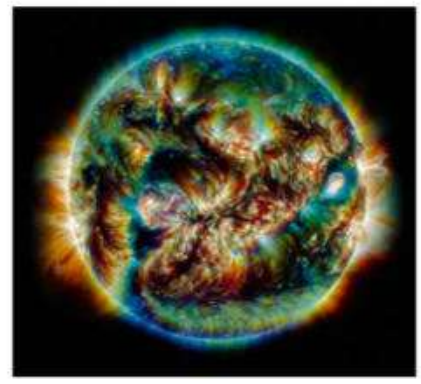

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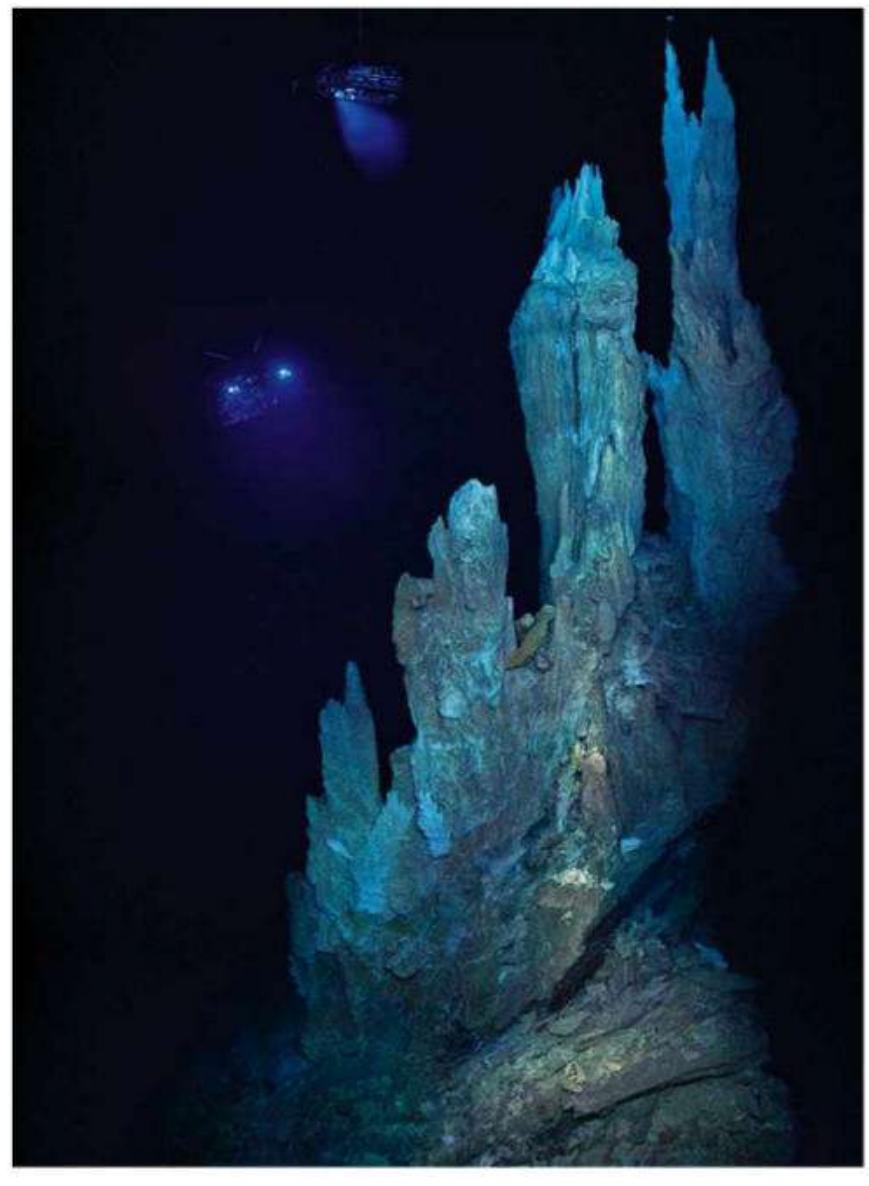

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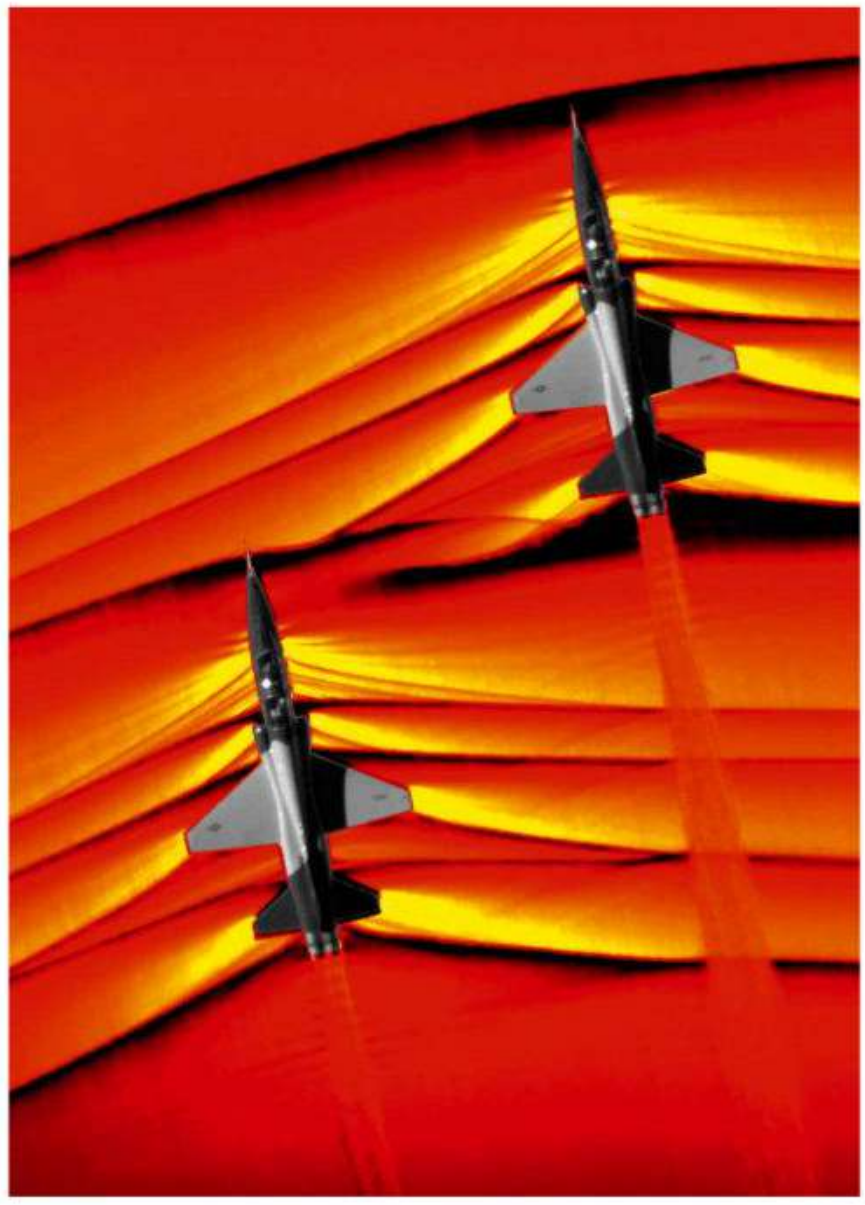

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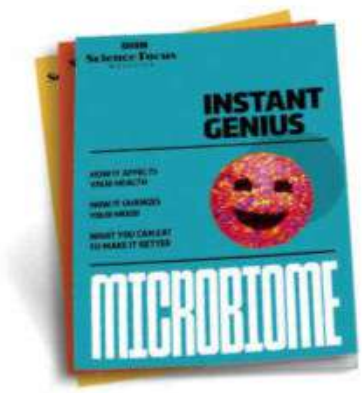

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EYE OPENER

Ancient calendar

ANCASH REGION, PERU

The Peruvian desert is home to the Chankillo astronomical site; an ancient, fortified ceremonial complex, complete with a temple, administration block and what is believed to be the earliest known solar observatory in the Americas.

The vertebrae-like structures on the right have been called the Thirteen Towers, and these are what the astronomers used as an artificial horizon. Built sometime in 250-200 BC, ancient stargazers could use the horizon as a year-round calendar as it spans the entire setting and rising arc of the Sun. By determining the Sun's position they could accurately predict upcoming solstices and equinoxes, as well as being able to determine the date with a precision of one to two days. It's thought that this knowledge would help them plan seasonal harvests, as well as hold religious events.

The site was added to UNESCO's World Heritage List in July this year.

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EYE OPENER

Leap from leaf to leaf

SABAH, BORNEO

This tiny creature may resemble an angry cotton ball, but it is in fact the nymph of a flatid planthopper. Able to jump over 100 times its body length, the flatid planthopper can cover vast spans of Borneo's rainforests.

Their powerful jump uses the same mechanism by which an archer uses a bow and arrow. "The arm muscle [of an archer] pulls back on the arrow slowly, then lets go to release all that energy at one time," explains Prof Malcolm Burrows, a zoologist from the University of Cambridge.

"The nymphs have huge muscles in their thorax that they contract very slowly. Their whole exoskeleton bends, then the muscles are released suddenly, propelling them forward."

While some flatids are pests to olive groves and vines, most go about their business not doing much harm, Burrows says. "They really are nice little insects that people should take notice of."

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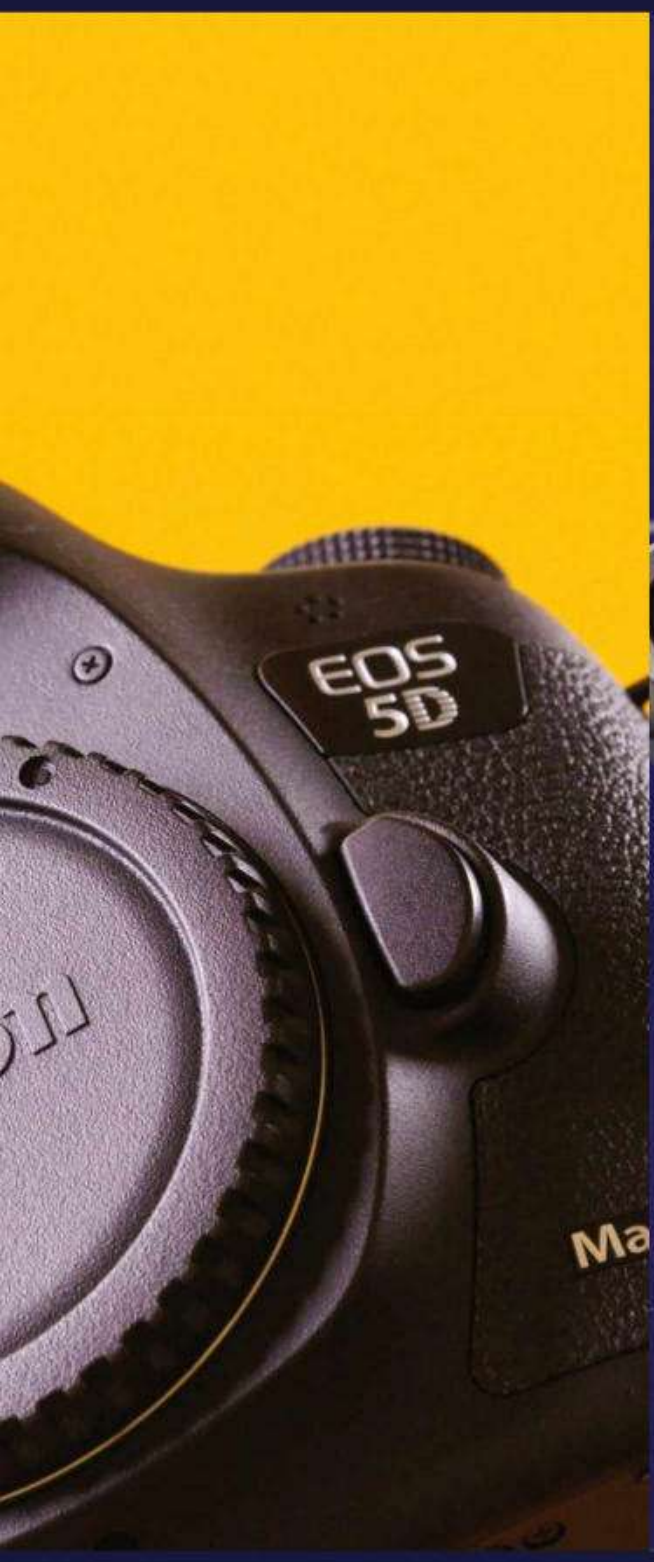

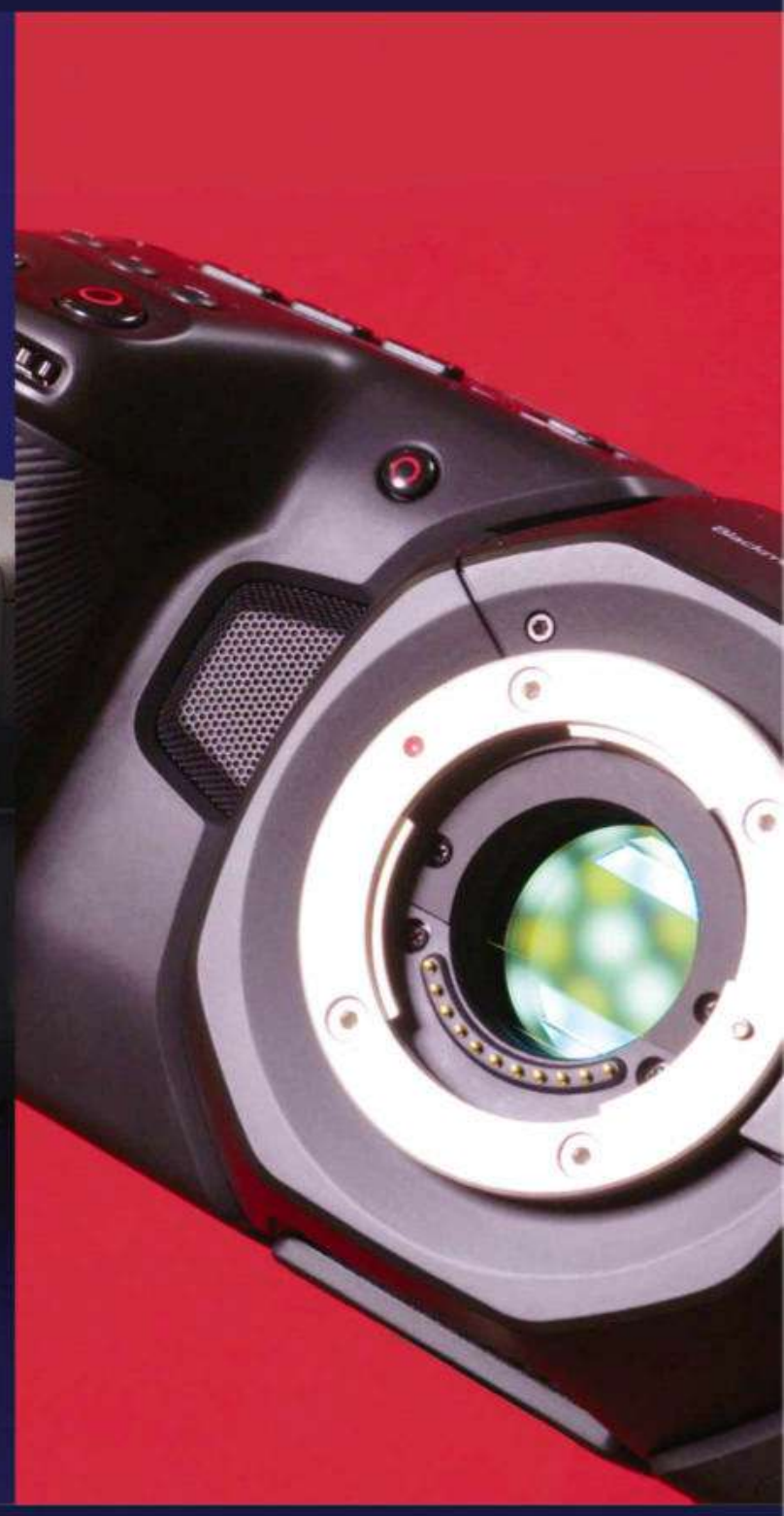

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

Crypto cash

I read with interest Aleks Krotoski's column about the marginalisation of some groups in society due to the diminishing role of cash (August, p64). A large group mentioned in the article were the underserved and unbanked. We have a solution available, in the form of cryptocurrencies. Literally designed to be digital cash, with no complicated application forms to fill in and no credit history needed, you don't even need a physical or fixed abode. The tech offers more than just cash, it can also give you a digital identity, which for some people will be a major step up in their ability to interact.
Steve

Cryptocurrency could offer an alternative to cash, says Steve

There have been several approaches to using blockchain services for the underserved and unbanked, from providing a stable ID to access government and health services (like in the city of Austin, Texas) to offering an alternative method of earning. But these services require access to technology (smartphones, tablets) that isn't universal, usernames and passwords as tokens of authentication (if using publicly accessible tech), and organisations that will accept cryptocurrencies for services. Cryptocurrency values also fluctuate wildly, benefitting people who have the resources available to lose a bet. I commend the innovators trying to address this issue using this technology, but at the moment, it's not a safe investment for most.
Aleks Krotoski, *BBC Science Focus* columnist

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a bundle of thought-provoking books from **Dorling Kindersley** – just the thing for curious minds. The prize includes *The Science Of Living* by Dr Stuart Farrimond, *The Green Grocer* by Richard Walker, and *The Most Important Comic Book On Earth* by authors that include Jane Goodall, Chris Packham and Ricky Gervais. **dk.com**

Should we extend our lives?

Your August issue has a piece on the CRISPR gene-editing tool and its potential to eliminate congenital diseases (p52). We all want to live longer and to have our loved ones with us for as long as possible, but what is the cost to the planet of our burgeoning population? The Earth supports close to eight billion people. The US has the highest per capita carbon footprint, while China, due to its huge population, is the biggest polluter overall. Should China ever reach the USA's per capita carbon footprint, humanity would probably be doomed.

Exponential population growth since the end of WWII is not due to increasing birth rate, but increase in life expectancy brought about by advances in medicine, food production and hygiene. Reducing the birth rate would not be a perfect solution. In fact, birth rates have slowed to below replacement levels in some countries. An ageing population brings its own problems of how to pay to support people into old age. Why do we continue this quest for immortality, rather than devoting scientific brain power to global warming, deforestation, habitat destruction and pollution?
Keith Riley

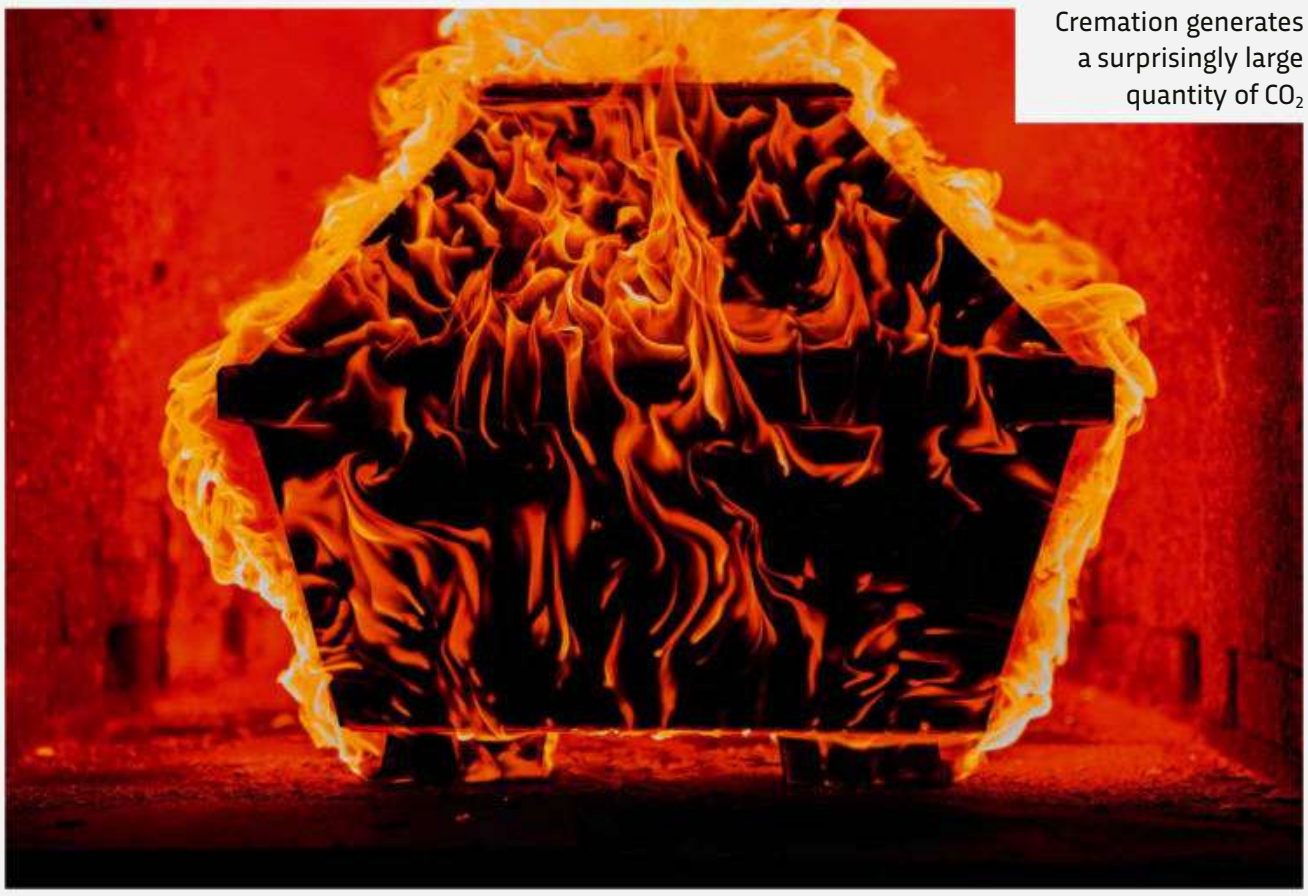
Heavy ashes?

I was stunned at the figure of 536kg of CO_2 per body cremated (Summer, p46), then I tried to reason it out. The average US woman

Vaccinations and other medical advances have dramatically increased our life expectancy

"WHAT WE REALLY NEED, AS STEWARDS OF THIS PLANET, IS TO PROTECT OUR NEIGHBOURS"

PROF RANDI ROTJAN, P55



Cremation generates a surprisingly large quantity of CO_2

GETTY IMAGES X2, ALAMY

weighs roughly 80kg, so that means that a woman generates seven times her weight in CO_2. Is this correct?
Eleanor Eunson

I am rather confused by the figure of 536kg of carbon dioxide produced by a body when it's cremated. I have seen another figure quoted as 500lb plus, still obviously quite a lot, but only about half as much. The circumstances concerning a cremation can vary widely, but would the result be that much different?
John

That 536kg figure incorporates the energy required to heat the furnace so that's why it's higher than the carbon within the human body. I think the term "produced by the body" in the sentence was not helpful in this context, so I can only apologise. It should have read "produced by the process of cremation".
Jules Howard, *BBC Science Focus* contributor

Boot out that idea!

I read the *Letter Of The Month* in the August issue (p12) regarding soccer pitch dimensions being a possible standard unit of area, but this wouldn't work. FIFA has a recommendation (not a rule) of 105 x 68m for a soccer pitch – a total of 7,140m^2. National associations do not have to work to this recommendation. For example, English FA allows between 90m and 120m long, and for width between 45m and 90m, giving a maximum area of 10,800m^2 and a minimum of 4,050m^2. German Bundesliga, meanwhile, allows 85m or 125m long, and up to 80m width, giving a maximum area of 10,000m^2 and a minimum of 6,800m^2.

Therefore, I suggest soccer pitch dimensions would be far from a standard both internationally and even within a country. Maybe international swimming pools or even professional tennis courts if you wanted sporting you could perceive?
David Tordoff

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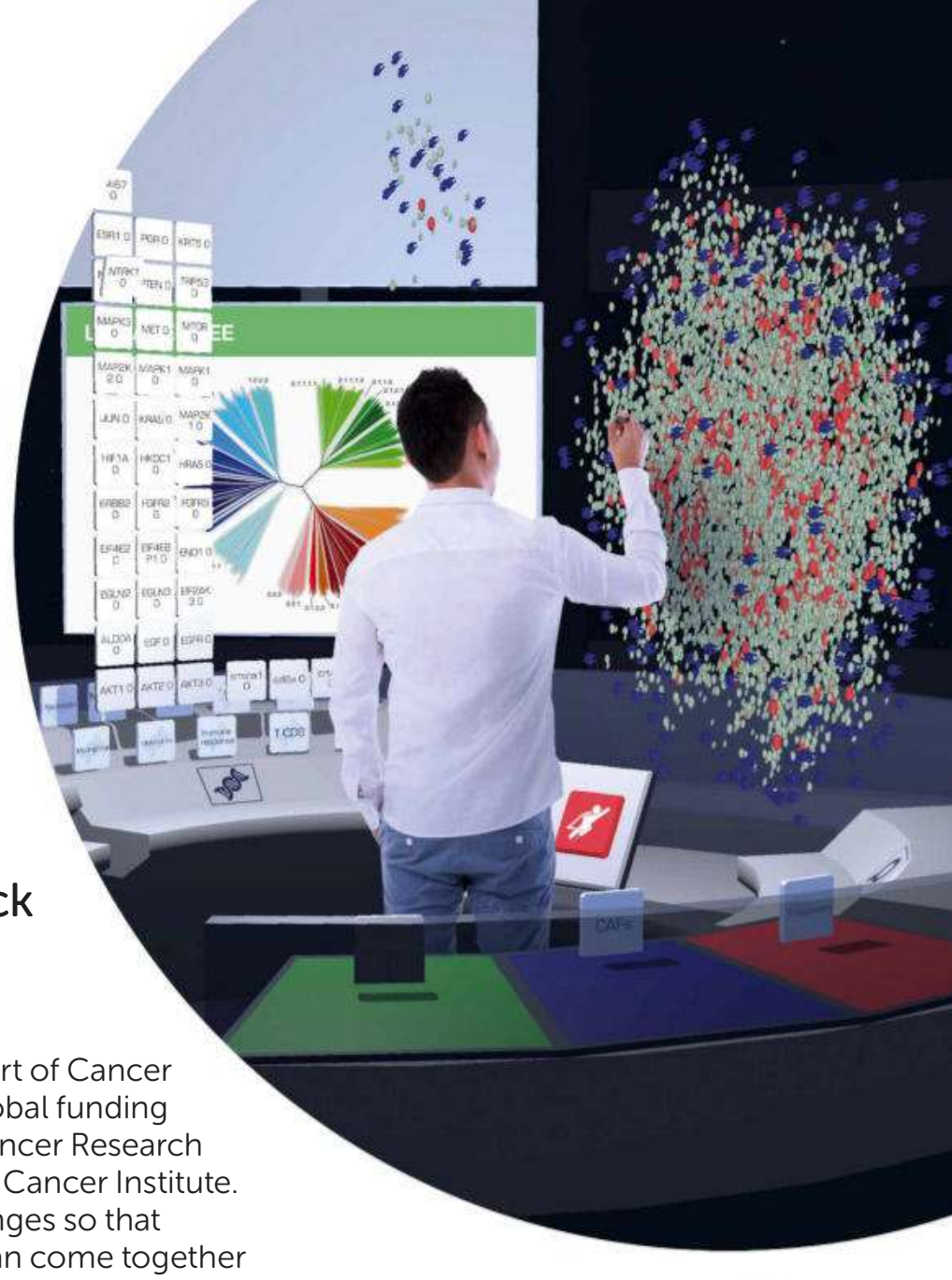
Saving lives with virtual reality



Cancer Research UK is helping scientists beat cancer by developing technology that will unlock its secrets. You can help beat the disease too.

Tumour biopsies play a crucial role in a cancer patient's journey. They provide doctors with vital information to guide their diagnosis and the patient's treatment.

But to better understand cancer, doctors need to know more about a tumour: what types of cells are in it, how many cells there are, what they're doing and where they're located. Biopsies are useful, but the technologies currently in use look at the cell samples individually, rather than in the context of their surrounding environment. They provide researchers with vital information about the separate components of a tumour, but not an overview of how the cells interact with the tumour as a whole.

A detailed, 3D picture of a tumour would help doctors and scientists to develop new ways to diagnose and treat cancer. And that's precisely what the team behind IMAXT is trying to provide them with.

IMAXT (Imaging and Molecular Annotation of Xenografts and Tumours) is combining existing techniques and developing new ones to build the first computerised 3D tumour that can be viewed in virtual reality. The scientists involved in the project come from a broad spectrum of research fields – medicine, astronomy, computer programming, molecular biology and virtual reality – and they're pooling their expertise to create a system capable of simulating a tumour's internal architecture.

The IMAXT team is part of Cancer Grand Challenges, a global funding initiative founded by Cancer Research UK and the US National Cancer Institute. It sets ambitious challenges so that diverse, global teams can come together and think differently, with the aim of making the progress against cancer the world urgently needs.

In 2017, the IMAXT team secured £20m of funding over five years, after impressing the Cancer Grand Challenges' panel of eminent scientists with their proposal to create 3D maps of tumours.

The team, like many scientists involved in the fight against cancer, is working on ways to find the disease sooner and stop it from spreading or returning after it's been treated. But to fund more bold ideas like IMAXT Cancer Research UK needs your help and one way that you can do that is by leaving a gift in your Will.

Gifts in Wills fund a third of Cancer Research UK's life-saving research. Thanks to its generous supporters, the charity is the largest independent funder of cancer research in the world and the only one researching over 200 types of the disease. Cancer Research UK aims to prevent more cancers, diagnose them earlier, develop the best treatments and ensure that each patient receives the treatment that's right for them. Your pledge will help Cancer Research UK, and the scientists it funds, achieve these goals so that future generations won't have to fear cancer.

A gift that saves lives

In the last 40 years, Cancer Research UK has helped double cancer survival in this country. But it doesn't intend to stop there. A gift in your Will can help fund life-saving research that will help beat cancer for future generations. There are many different types of gifts you can leave in your Will, such as a specific amount or an item, but a residuary gift is likely to be the most valuable way to pledge. As it's less likely to be affected by inflation, it's the best way to ensure the value of the gift you want to make is received.

IMAGE CREDIT: FLAMINIA GRIMALDI, OWEN HARRIS, ROBBY BECKER. SUIL INTERACTIVE, IRELAND

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Together we will beat cancer

Cancer Research UK is a registered charity in England and Wales (1089464), Scotland (SC041666), the Isle of Man (1103) and Jersey (247).

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DISCOVERIES

ENVIRONMENT

WHAT WE LEARNED FROM THE IPCC'S LATEST GLOBAL CLIMATE REPORT

The UN's Intergovernmental Panel on Climate Change's sixth assessment report on the state of the planet's climate makes for sobering reading, but it's not all bad news

SHUTTERSTOCK

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was formed. It is a body made up of the world's leading climate scientists, with members from 195 countries. Back in 1990 it issued its first report warning of the potential dangers of rising greenhouse gas emissions. Here are the key points from its latest report, released in August this year.

Choked brain Air pollution linked to increased risk of dementia p23 **Primate promenade** Baboons compromise so they can walk together p22 **Spaced out** Astronomer Photographer of the Year p24 **Current climate** Ocean movements affected by global warming p26

Extreme rainfall due to climate change led to scenes like this in India in July and August this year

Human activity over the last 100 years is to blame for increases in temperature

Human activities have changed the climate and led to a significant increase in heatwaves, floods, droughts and wildfire. The researchers estimate that emissions of greenhouse gases from our activities are responsible for raising global surface temperatures by around 1.1°C since 1850-1900, with the last five years being the hottest on record. If this is allowed to continue, then global temperature is expected to reach or exceed the limit of 1.5°C of warming laid out in the Paris Agreement (a legally binding international treaty on climate change) within the next 20 years.

"This report is a reality check," said IPCC Working Group co-chair Dr Valérie Masson-Delmotte. "We now have a much clearer picture of the past, present and future climate, which is essential for understanding where we are headed, what can be done, and how we can prepare."

Climate change is affecting every region

If global warming is kept to 1.5°C, we will still see an increase in heat waves, along with longer warm seasons and shorter cold seasons. But if that figure reaches 2°C, heat extremes would more often reach critical thresholds where they can cause serious issues for agriculture and health.

"Climate change is already affecting every region on Earth, in multiple ways. The changes we experience will increase with additional warming," said IPCC Working Group co-chair Panmao Zhai.

"The next two decades are particularly critical"

It's about more than rising temperatures

Though the focus tends to be on increasing temperatures, climate change is having a significant impact on global patterns of rain, wind and snow, bringing more intense rainfall and flooding, as well as severe periods of drought.

Rainfall is likely to increase in high latitudes, and decrease over large areas of the subtropics. Local changes are also likely to occur to monsoon seasons. Rising temperatures will accelerate the loss of seasonal snow cover, the melting of glaciers and ice sheets, and the loss of summer Arctic sea ice, the report states.

"The report finds strengthened evidence that human-caused warming of climate is intensifying the global water cycle, including its variability and the severity of very wet and very dry weather and climate events affecting all regions," said report author Prof Richard Allan, from the University of Reading.

Extreme sea level events that previously occurred once in 100 years could happen every year by the end of this century, the report states.

Current measures are not enough

The report finds that unless there are immediate, large-scale reductions in greenhouse gas emissions, limiting warming to close to 1.5°C or even 2°C will be beyond reach.

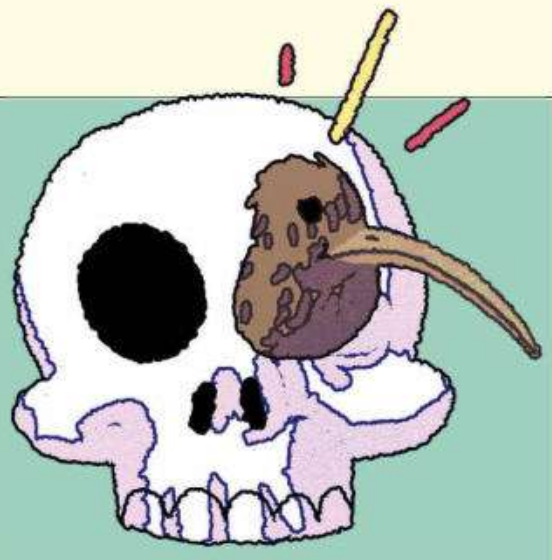
"If there was still a need for proof that climate change is caused by human activities, this is the report that provides it. The report goes well beyond the previous IPCC assessment of 2013 and resolves all major uncertainties, to provide the clearest picture yet of the effect of human activities on the climate and on weather extremes," said report author Prof Corinne Le Quéré, from the University of East Anglia.

"The message could not be clearer, as long as we continue to emit CO_2 the climate will continue to warm and the weather extremes – which we now see with our own eyes – will continue to intensify. Thankfully, we know what to do: stop emitting CO_2."

There's still time to act

It's not all bad news. Significant and sustained reductions in emissions over the coming decades could limit climate change and even see global temperatures stabilise.

"The next two decades are particularly critical. It will require sustained and concerted global efforts targeting rapid reductions in CO_2, methane and other greenhouse gases to limit warming to 1.5°C in line with the Paris Agreement," said author Shayne McGregor, an associate professor from Monash University.



KIWIS

If you want the best chance of surviving societal collapse, maybe think about moving to New Zealand. A study carried out at Anglia Ruskin University ranked the ability of different nations to grow food, produce goods, maintain a power supply and protect their borders, and the Kiwis came out on top.

BEAVERS

Wild beaver numbers have rocketed to more than 1,000, a survey by NatureScot has found, with families of animals making their homes in more than 250 locations across Scotland.

Good month

Bad month

COUCH POTATOES

Those of us who spend a lot of time sitting on the sofa tend to be a bit on the heavy side, but a team from Boston University has found that this may not simply be down to a lack of physical activity. Exposure to metabolism-disrupting chemicals found in furniture may be triggering fat cell production, they say.

DOG OWNERS WHO LIE

Pooches know when they are being lied to, a study at Vienna University has found. The researchers tested 260 dogs of various breeds by placing a hidden treat in one of two bowls and then pointing to one of them. Half of the pups ignored the human's advice when they saw them pointing to the wrong bowl.

GETTY IMAGES X2 ILLUSTRATIONS: KYLE SMART

ZOOLOGY

What's Ape: Chimps say hello and goodbye when they meet, just like us

You may have been told that it's rude to start eating before everyone is ready, or that you shouldn't leave the table before your guests have finished. As it turns out, apes are no different.

Like us, chimpanzees and bonobos make a common gesture that signifies the start and end of a social interaction – a mutual gaze or a vocal signal is enough to show they're ready to play, for example.

These signals could represent the start and end of a mutual agreement, which researchers say challenges the current idea that only humans make joint commitments.

"Joint commitment is the driving force, the glue, of our joint actions, whether at large scale, like long-term projects, or small scale, such as lunch," explained one of the study's authors Dr Raphaela Heesen, from Durham University.

Though many animals cooperate to achieve a goal, scientists thought a joint commitment had to involve a sense of obligation. However, when Heesen and colleagues noticed two bonobos making gestures at one another after their grooming had been interrupted, the team proposed a new definition: that joint commitment requires an agreement to be set up beforehand, and then ended at a mutually decided time. If so, then the behaviours they'd witnessed between the bonobos could be seen as the agreed return to their prior commitment to grooming each other.

Using footage of over 1,200 ape interactions, such as grooming and playing, the team showed that the two species did communicate before and after a joint activity, using gestures such as holding hands, touching each other or butting heads, as well as vocalisations, mutual gazing and facial expressions.

Before playing with their friends, bonobos exchanged mutual gazes 90 per cent of the time, while two chimpanzees would communicate that they were ready to start 69 per cent of the time. The two ape species would perform exit signals even more often than on entry, with 92 per cent of bonobo and 86 per cent of chimpanzee interactions ending with some form of gesture or gaze.

What if the two apes couldn't agree on the end of an interaction? "We very rarely observed such cases of disagreement," said Heesen. "When we did, the two individuals communicated before coming to a mutual agreement to end."

HISTORY

Babylonians were using Pythagoras' Theorem over 1,000 years before he was born

An ancient clay tablet shows that the Babylonians used Pythagorean triples to measure accurate right angles for surveying land

Students may complain that Pythagoras' Theorem has no real-world uses, but a 3,700-year-old tablet demonstrates that the formula was being used long before Pythagoras even wrote it down. The artefact, named Si.427, shows how ancient land surveyors used geometry to draw boundaries accurately.

First discovered in central Iraq in 1894, Si.427 sat in a museum in Istanbul for over a century. It was only when mathematician Dr Daniel Mansfield from the University of New South Wales, Australia, began to study the clay tablet that its meaning was uncovered.

"Si.427 dates from the Old Babylonian (OB) period – 1900 to 1600 BCE," said Mansfield. "It's the only known example of a cadastral document from the OB period, which is a plan used by surveyors define land boundaries.

"This is from a period where land is starting to become private – people started thinking about land in terms of 'my land and your land', wanting to establish a proper boundary to have positive neighbourly relationships. And this is what this tablet immediately says. It's a field being split, and new boundaries are made."

As many will remember from their school days, Pythagoras' Theorem states that the sides of a right-angled triangle obey the formula $a^2 + b^2 = c^2$, where a and b are the lengths of the short sides, and c is the length of the longest side.

A Pythagorean triple is a set of numbers – usually whole numbers – that fits this relation, such as 3, 4 and 5, or 5, 12 and 13. Any triangle with sides of these lengths must be a right-angled triangle – a fact that is useful for marking out accurate rectangles. The surveyor who created Si.427 used Pythagorean triples to make accurate right angles, making it the earliest known example of applied geometry.

However, the number system used by the Babylonians was different from the one we use now. Ours is a system called base 10: numbers are written by breaking them down into hundreds, tens, units, and so on. The Babylonians used the more complex base 60, similar to how we keep time: 60 seconds make up one minute, and 60 minutes make up one hour meaning that only certain Pythagorean shapes can be used.

"Nobody expected that the Babylonians were using Pythagorean triples in this way, it is more akin to pure mathematics, inspired by the practical problems of the time," explained Mansfield. "The discovery and analysis of the tablet have important implications for the history of mathematics. For instance, this is over a thousand years before Pythagoras was born."

Si.427 shows the earliest known use of applied geometry, more than 1,000 years before Pythagoras started studying triangles

HEALTH

Fasting may help protect against infection

Study in mice suggests the effect is partly due to changes in the animals' gut microbiomes

Many people claim that time-restricted eating or intermittent fasting can lead to health benefits

Whether it's 5:2, 16:8 or Eat Stop Eat, intermittent fasting diets have skyrocketed in popularity in recent years. Proponents of the diets claim they bring all manner of health benefits, from simple weight loss to significant falls in blood pressure, blood sugar and cholesterol.

Now, a study carried out in mice at the University of British Columbia in Canada suggests that fasting may also help to protect us from infection.

When humans or animals develop an infection, they often lose their appetite. However, it has so far remained unclear as to whether fasting could protect a host from infection or increase their susceptibility to it.

To test this, the researchers fasted a group of mice for 48 hours and orally infected them with *Salmonella enterica serovar Typhimurium* – a bacteria responsible for a high proportion of cases of gastroenteritis in humans. A second group of mice received regular access to their usual diet before and during infection.

The researchers found that the fasted mice had fewer signs of bacterial infection and very little intestinal tissue damage compared to the fed mice. However, when they repeated the experiment with fasted mice infected with *Salmonella* intravenously, the protective effect was not seen.

Similarly, the protective effect was not seen when they repeated the experiment using germ-free mice – mice bred to lack a normal microbiome. This suggests that some of the effect was due to changes in the animals' gut microbiomes.

UNIVERISTY OF NEW SOUTH WALES, GETTY IMAGES

> **"The fasted mice had fewer signs of bacterial infection and little intestinal tissue damage"**

When food is limited, the microbiome appears to sequester the nutrients that remain, preventing pathogens from acquiring the energy they need to infect the host, the team say.

"We saw an overall change in the composition of the microbiome, meaning an increase in some bacteria and a decrease in other bacteria," said co-author Dr Bruce Vallance.

"However, we did not show in our study which bacteria specifically are responsible for the protective effect, just that the microbiome as a whole is mediating most of the protective effect of fasting since mice lacking a microbiome – germ-free mice – are not as protected from the infection."

The researchers now plan to investigate the effect of fasting on the microbiome with the aim of establishing whether the absence or presence of specific bacteria are responsible for the protective effect.

In numbers

74 million

The number of heat-related deaths that could be prevented worldwide if humans are able to cut greenhouse gas emissions to zero by 2050.

8,700m

The altitude a great snipe was recorded flying at on its migration from Sweden to Central Africa. That's just 150m lower than the peak of Everest.

40°C

The temperature that UK summers could regularly reach in the coming years, according to the Met Office.

PSYCHOLOGY

Bizarre 'alien simulation' study shows how COVID panic-buying was a natural response

New research from the University of New South Wales has demonstrated how people react differently to change

Panic-buying: it's rarely helpful, often damaging and always divisive. But it also might be a natural human response to sudden uncertainty, rather than just being a selfish action. At least, that's what's suggested by a study comparing people's responses to rapid and gradual changes.

To examine this issue, researchers from the University of New South Wales, Australia, enlisted the help of a pair of aliens. Well, not real aliens. In a virtual simulation, 35 participants were tasked with attaining as many 'alien dollars' as possible by selling a selection of chemicals to one of two extraterrestrials. In each 'sale round', participants had to pick two chemicals before choosing which alien to sell to. However, unknown to the humans, only one of these chemicals would determine how much the selected extraterrestrial would pay.

Over a few rounds, participants quickly learned the combination of chemicals and alien that would earn the most money (up to $15) per sale.

However, midway through the experiment, the reward pattern secretly changed: participants who used their usual winning combination were given a random payout (between $8 and $22). Immediately, they started trying vastly different strategies.

"As soon as we added an element of uncertainty, the participants started looking for new ways to complete the task," said co-author Dr Adrian Walker, a psychologist from the University of New South Wales. "The kicker is that in all cases, the best thing they could do was use their old strategy."

But here's the crucial part: when the level of randomness was introduced slowly over the course of several rounds (from $14 to $16, then $13 to $17, and finally $8 to $22), a different group of 35 participants didn't radically change their tactics.

"The participants' behaviour didn't change dramatically, even though the uncertainty eventually reached the same levels as in the first experiment," said Walker.

Walker sees this experiment as evidence of 'boiling frog syndrome', where humans only tend to alter their behaviour in the face of sudden change – think panic-buying in a pandemic – but not when faced with slow-moving issues.

"We can see this pattern in a lot of real-world challenges, like the climate change crisis," Walker said. "When change is slow and barely noticeable, there's no sudden prompt to change our behaviour, and so we hold to old behaviours. Trying to get action on climate change is a lot like the boiling frog fable. If you put a frog in a pot and boil the water, it won't notice the threat because the water is warming gradually. When it finally notices, it is too late to jump out."

It's hoped that this research could help develop a computational model that predicts what degree of uncertainty could spur human behavioural change.

"Given how many decisions we make under uncertainty in our everyday lives, the more we can understand how these decisions are made, the more we hope to enable people to make good decisions," said Walker.

During the pandemic, food shortage fears led to panic-buying by some consumers

GETTY IMAGES X2

"When change is slow and barely noticeable, there's no sudden prompt to change our behaviour"

HEALTH

Rise in childhood short-sightedness linked to increase in screen time and time spent indoors during COVID-19

More time spent indoors during the COVID-19 pandemic may have caused a significant rise in childhood short-sightedness, according to a new Hong Kong study. Published in the *British Journal Of Ophthalmology*, the findings were based on the ongoing Hong Kong Children Eye Study, which continually researches the eye conditions of children aged six to eight.

The study found that 19.5 per cent of the 709 children recruited at the start of the pandemic (between December 2019 to January 2020) developed short-sightedness over the course of eight months.

The overall estimated one-year incidence of short-sightedness for COVID-era six-year-olds was 28 per cent – much higher than the 17 per cent found in children studied pre-pandemic.

The researchers note that these changes coincided with a reduction in the time the children spent outdoors – from around 75 minutes a day pre-pandemic to 24 minutes during the pandemic.

Screen time among the children also drastically increased during this period, from two and a half hours a day, to seven hours.

The authors highlight that this data relied on questionnaires, which could impact the accuracy of the research. Also, as it was a local study to Hong Kong, the researchers couldn't say whether the same results would be seen in children in the UK and other countries.

"Despite all these insurmountable study limitations, our initial results still show an alarming myopia progression that warrants appropriate remedial action," the researchers concluded.

James S Wolffsohn, professor of optometry at Aston University, who did not take part in the research, told *BBC Science Focus:* "During the epidemic, lifestyles have changed, such as the amount of time spent viewing digital screens, homeschooling and the duration of time spent outdoors. At least nine peer-reviewed published studies – not including this new Hong Kong study – have identified an increase in myopia progression during the pandemic."

Fortunately, though, the effect may not be permanent. "One study found this myopic progression was reversed partially after lockdown, suggesting that both eye focus spasm and structural changes contributed to this accelerated rate," explained Wolffsohn.

Less time outdoors and more screen time may have led to increased prevalence of short-sightedness during the pandemic

HEALTH

Air pollution linked to an increased risk of dementia

A small rise in the number of fine particulates in the air can lead to a 16 per cent greater risk of developing dementia

Air pollution has long been known to be a contributing factor for a whole host of respiratory and cardiovascular conditions, but now scientists at the University of Washington have provided evidence that poor air quality can significantly raise the risk of dementia.

The researchers compared findings from the long-running Adult Changes in Thought (ACT) study, which looks at the incidence of dementia that began in the 1990s, with detailed air pollution data dating back to the 1970s.

They concentrated on a type of pollution known as $PM_{2.5}$. These are particles or liquid droplets in the air with a diameter of less than 2.5 micrometres, about 30 times finer than a strand of human hair.

They found that each increase of one microgram of $PM_{2.5}$ per cubic metre of air was linked to a 16 per cent greater risk of all-cause dementia. For comparison, air in the most polluted areas of London has around 15 micrograms of $PM_{2.5}$ per cubic metre of air.

"We know dementia develops over a long period of time. It takes years – even decades – for these pathologies to develop in the brain, and so we needed to look at exposures that covered that extended period," said lead author Rachel Shaffer, who conducted the research as a doctoral student in the University of Washington.

"We had the ability to estimate exposures for 40 years in this region. That is unprecedented in this research area and a unique aspect of our study," she added.

While there are many other factors that are associated with an increased risk of dementia, such as diet, exercise and genetics, the researchers say that air pollution should now be recognised as a key contributing factor and that reducing people's exposure to air pollution could help reduce the burden of dementia.

"Over an entire population, a large number of people are exposed. So, even a small change in relative risk ends up being important on a population scale," Shaffer said.

"There are some things that individuals can do, such as mask-wearing, which is becoming more normalised now because of COVID. But it is not fair to put the burden on individuals alone. These data can support further policy action on the local and national level to control sources of particulate air pollution."

> **"Even a small change in relative risk ends up being important on a population scale"**

Olive baboons make compromises in their stride length so they can walk together as a troop

ZOOLOGY

Baboons wearing fitness trackers show that taking toddlers anywhere is a nightmare, no matter your species

When it comes to moving as a group, it seems that everyone has to make a compromise

Scientists have used fitness tracker technology on a troop of wild olive baboons to uncover how they stick together as a group.

The results of the research showed that travelling with a mix of ages and abilities requires compromise on the part of the long- and the short-legged – but it's the littlest baboons that draw the shortest straw.

"Anybody who has tried to walk with a toddler knows the challenges of moving with someone who has a different physical ability," said first author Dr Roi Harel, an ecologist at the Max Planck Institute of Animal Behavior.

"Small individuals pay disproportionate costs associated with maintaining group cohesion, and this might be because they have the most to gain from group membership."

The team worked with a troop of wild baboons at the Mpala Research Centre in Kenya. To record their data, they attached GPS trackers and accelerometers to the baboons. The readings from these trackers provided information on the movements of individual baboons, including their location, number of steps and locomotion speed.

While larger animals took longer strides – and required fewer steps than the smaller, younger baboons – the researchers found that all members of the troop made compromises so that they could match the pace of their nearest companion. They increased their stride when travelling next to larger individuals, and decreased their stride when with smaller ones.

"The dominant male clearly wields power over other baboons in one-on-one interactions," said Harel. "But when it comes to collective movement, it seems like a shared decision-making process drives the group."

A similar dynamic has been shown in bird flocks and may well be a general pattern that holds across species, whether they walk, swim or fly.

GETTY IMAGES X2 ILLUSTRATION: KYLE SMART

They did what?

Scientists demonstrate that beer mats make poor frisbees

WHAT DID THEY DO?

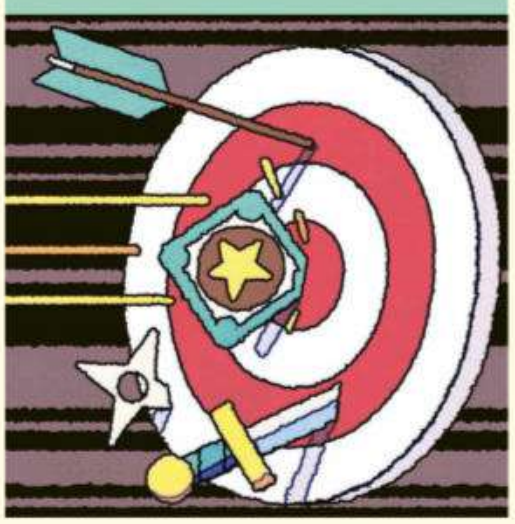
In a niche experiment, researchers at the University of Bonn designed a machine to throw beer mats and recorded their trajectories using a high-speed camera.

WHAT DID THEY FIND?

The action of gravity causes the beer mats to tip backwards shortly after being thrown. They unavoidably begin to drift off their course after 0.45 seconds, wending to the left if they are spinning clockwise, or to the right if they are spinning anticlockwise.
Now you know.

WHY DID THEY DO THAT?

Erm... just for fun.
"There is no application for the project," said the University of Bonn's Dr Carsten Urbach. "However, the problem is clear for laypeople and physicists alike. And it wonderfully illustrates the entire process by which the natural sciences acquire knowledge – from the observation to the theory and its experimental testing, right through to its adjustment and further development."



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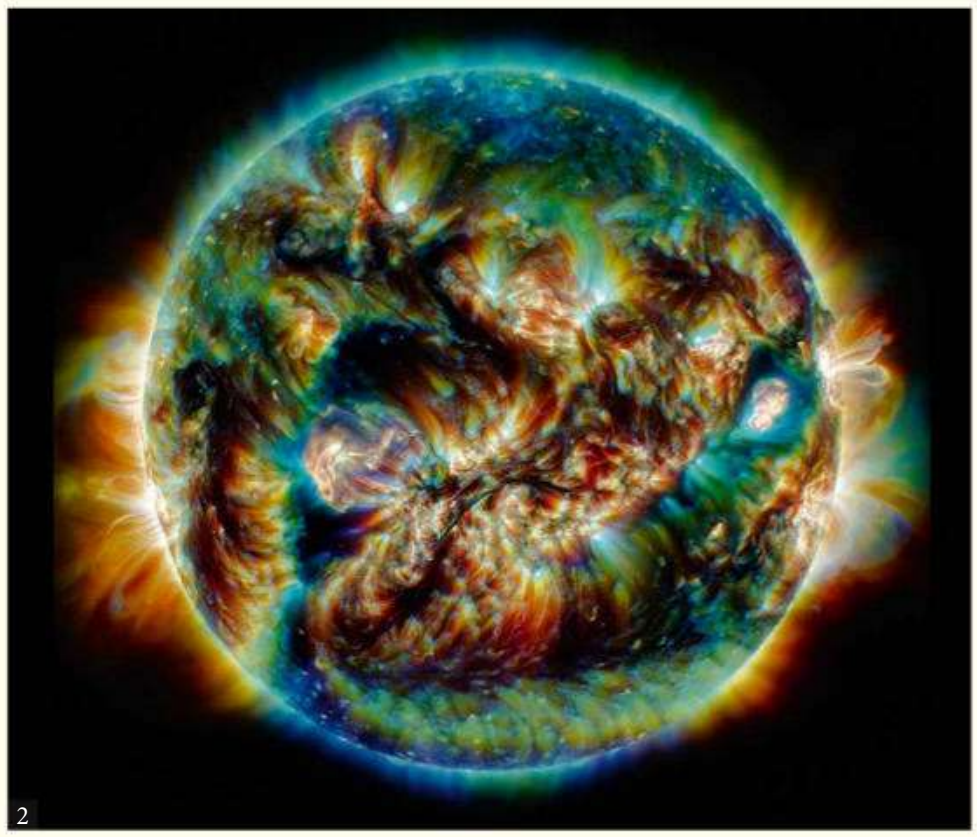
ASTRONOMY

Astronomy Photographer of the Year teases this year's shortlist

The contenders for the world's largest astrophotography competition have been chosen. The winners will be announced at an online ceremony on 16 September. Following the ceremony, a selection of the winning and shortlisted images will be displayed at an exhibition at the National Maritime Museum, London, from 18 September.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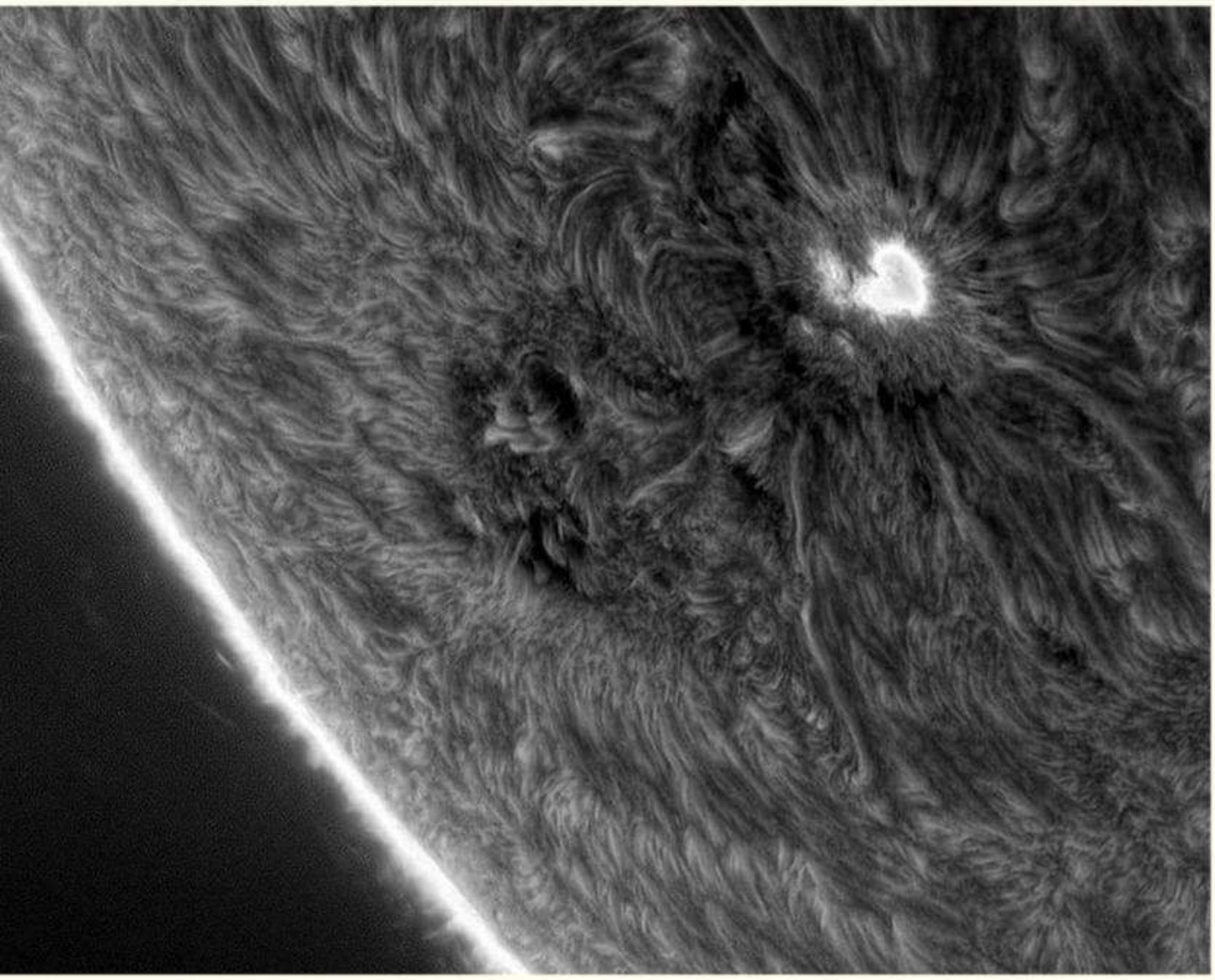


1. Lunar halo
by Göran Strand
This lunar halo was taken in a temperature of -16°C. This optical phenomenon forms when moonlight is refracted by ice crystals hanging in the atmosphere.

2. The tumult of the Sun
by Hassan Hatami
This image was created from data collected by NASA's Solar Dynamics Observatory. It shows the tumultuous currents that churn around the Sun's surface.

3. Alien throne
by Marcin Zajac
Locals living in the Badlands of New Mexico refer to rock spires as hoodoos, their otherworldly shape is formed from layers of soft and hard rock that have eroded over time. This particularly ornate example is photographed with the Milky Way in the background.

4. Iceland vortex
by Larryn Rae
The aurora borealis is shown here in a 250° panoramic shot. The ghostly lights are formed by charged particles emanating from solar winds that get trapped in the Earth's magnetic field.

5. Sunspot looking out into space
by Siu Fone Tang
Although the exact details of sunspot formation are not well understood, they coincide with areas on the Sun's surface with an increased magnetic field. These suppress the release of heat, making them thousands of degrees cooler than the surrounding area.

PROF PENNY HOLLIDAY
Oceanographer

"The ocean has this capacity for storing heat. This movement of heat around the globe keeps our climate nice for us to live in"

Horizons

The Atlantic Ocean's currents are slowing down. What could this mean for the UK climate?

The Gulf Stream, which brings the UK's clement weather, could be affected by this change

STUDIES HAVE FOUND THAT THE ATLANTIC MERIDIONAL OVERTURNING CIRCULATION (AMOC) IS SLOWING DOWN. WHAT EXACTLY IS THE AMOC ?

Put simply, it is large-scale ocean currents in the upper 1,000 metres of the Atlantic. The currents transport warm, salty water northwards throughout the Atlantic. When the water reaches the subpolar North Atlantic, the water gets cold, becomes dense and it sinks down to below 1,000 metres and it flows back southwards.

You can think of it as a global conveyor belt, like the ones you see in the supermarket.

WHAT INFLUENCE DOES THIS CONVEYOR BELT SYSTEM HAVE?

It's all about heat, it's like a giant radiator system, if you like. The North Atlantic Ocean is transporting an enormous amount of heat northwards, from the tropics and subtropics into the subpolar ocean, the area between the UK, Iceland, Greenland and Canada.

The waters around the UK would be much colder if you didn't have this heat through the Atlantic in this overturning circulation. You can think of it as sort of a battery for the atmosphere.

The AMOC is incredibly important for the weather and the climate that we receive. In fact, the Gulf Stream is part of the AMOC, and is also part of the giant subtropical gyre that circulates horizontally. The subtropical gyre is wind-driven and will keep on circulating even as the world heats up, but as the AMOC slows then that part of driving force of the Gulf Stream slows and so the entire current system as a whole slows down.

One nice statistic that is quite useful to reflect on is that the heat held within the top one metre of the ocean contains as much heat energy as the whole of the atmosphere. The ocean has this capacity for storing heat. This movement of heat around the globe keeps our climate nice for us to live in. If all of the heat was just concentrated in the tropics, then they'd be too hot to live in and everywhere else would be too cold. That's the importance of the ocean circulation to us, the way it modulates our climate and our weather.

HOW HAS THE AMOC BEEN CHANGING?

How it's going to change in the future is the critical question, because the AMOC is so important for the climate and weather that we have in the UK that we really need to know how it's going to change. The bad news is that we don't have high confidence in those predictions, but all climate models show a slowing of the overturning circulation over the next few decades. With the low emissions scenario it takes longer to get to a low point, but in the high emissions scenarios it might only be another 50 years before it reaches that low point.

WHY IS THE SHIFTING OF OCEAN HEAT IMPORTANT FOR THE CLIMATE?

In the model projections, our climate is going to change over time with our carbon emissions. It's quite difficult to separate out the effects of a slowing of the overturning circulation from all the other effects of the ocean and the atmosphere. They interact with each other. So actually being able to pick out what a slowdown in the overturning circulation would cause is quite difficult.

But we think that a slowing of the AMOC has the effect of cooling parts of the ocean west of the UK because less heat is being carried northward through the Atlantic Ocean. So that distribution of heat from the tropics to the subpolar areas slows down a bit. That part of the ocean gets a bit colder and doesn't warm as fast as the rest of the world. That has a direct impact on our weather.

In the UK at the moment, the weather is getting wetter and warmer, and there's more extreme weather. But with the slowdown in the AMOC, some of that is counteracted a little bit. And that's because if there's not as much warming in the Atlantic Ocean then that will have an impact on things like where the jet stream sits. If the jet stream moves north of the UK, which is something that could happen as the AMOC slows down, then all of our weather will become drier, because all of the movements of the storms that bring our rain might run north of the UK. But it's unclear

specifically what a weakening of the AMOC does.

DOESN'T SALINITY ALSO PLAY A LARGE ROLE IN OCEAN CIRCULATION?

What's critical for the overturning circulation to take place is the fact that the Atlantic is a salty ocean. As the upper 1,000 metres of the water moves through the tropics and the subtropics it loses freshwater. There's lots of evaporation, so the water becomes saltier and saltier as it's travelling to the poles.

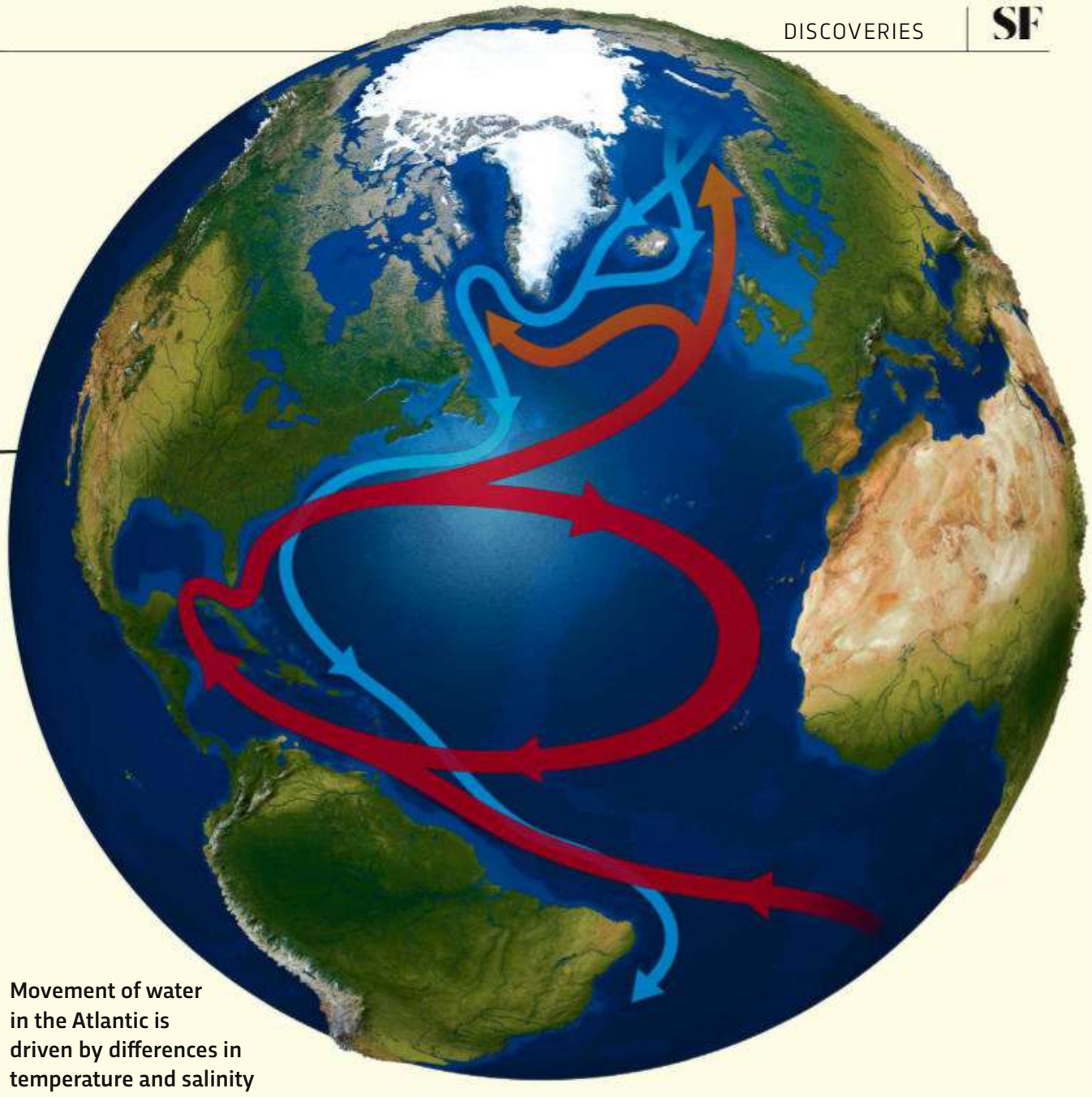
That level of salinity is really important because when the water is cold and salty it becomes very dense. That's what makes it sink to the bottom of the ocean basins. If the water isn't as salty, it'll still cool, but it'll stay closer to the surface. It won't sink so deep.

The models all show that the AMOC slows because it becomes less salty. There are many factors at play that are making it less salty, including changes in precipitation levels and meltwater coming from the Greenland ice sheet. Water that's less salty is less dense, and so less of it sinks, and it doesn't sink as deep, which slows the overall circulation down.

HOW CONFIDENT ARE WE THAT HUMAN-MADE CLIMATE CHANGE IS RESPONSIBLE?

We have high confidence that the projected decline that's going to happen to the AMOC in the future is driven by human carbon emissions. There has been a lot of work done with a model that allows you to test the effect on the climate in the ocean made by changes in carbon emissions. You can find any emissions and it'll tell you how it would have looked if there hadn't been any emissions.

We have a real challenge on our hands because we only have direct observations of the strength of the overturning circulation from 2004 onwards, which isn't very long.



Movement of water in the Atlantic is driven by differences in temperature and salinity

SCIENCE PHOTO LIBRARY

So if you're looking at trends over decades, we don't really have direct observations of the strength of the overturning circulation to help us understand how well we're doing in the models. But we have used proxies for estimating the strength of the past overturning circulation.

Things like evidence from the sea floor can show us whether we think the overturning circulation has slowed down over time. And previously, there have been studies which present evidence that it has been declining over the past 100 years.

But then there's also evidence that there hasn't been a decline over the past 100 years. And it's not clear at the moment, or rather we don't have high confidence, that we know how strong the overturning circulation has been, or how much variability there has been in the past 100 years. So that remains a challenge for us to keep improving our understanding.

It goes back to improving how well the models that we use actually represent the real ocean, because the interpretation of these proxy records is dependent on model behaviour. And if the behaviour of the models doesn't represent reality, then it makes us a little less confident in the ability of those proxy records.

WHAT CAN WE DO TO MEDIATE THE EFFECT?

Well, reducing emissions is the way to mediate the effect. One thing that's become very clear in the IPCC report [you can read more about the report on p15] is that there is evidence for a decline in the strength of the AMOC. What's important is for us to be able to understand what the process is, and the physical things that are happening in the ocean. We need to understand what they are and how they change over time to make sure that we get it right in the models.

PROF PENNY HOLLIDAY

Penny is a physical oceanographer. Her research is focused on the circulation and variability of the subpolar North Atlantic, and the role of the ocean in our changing climate.

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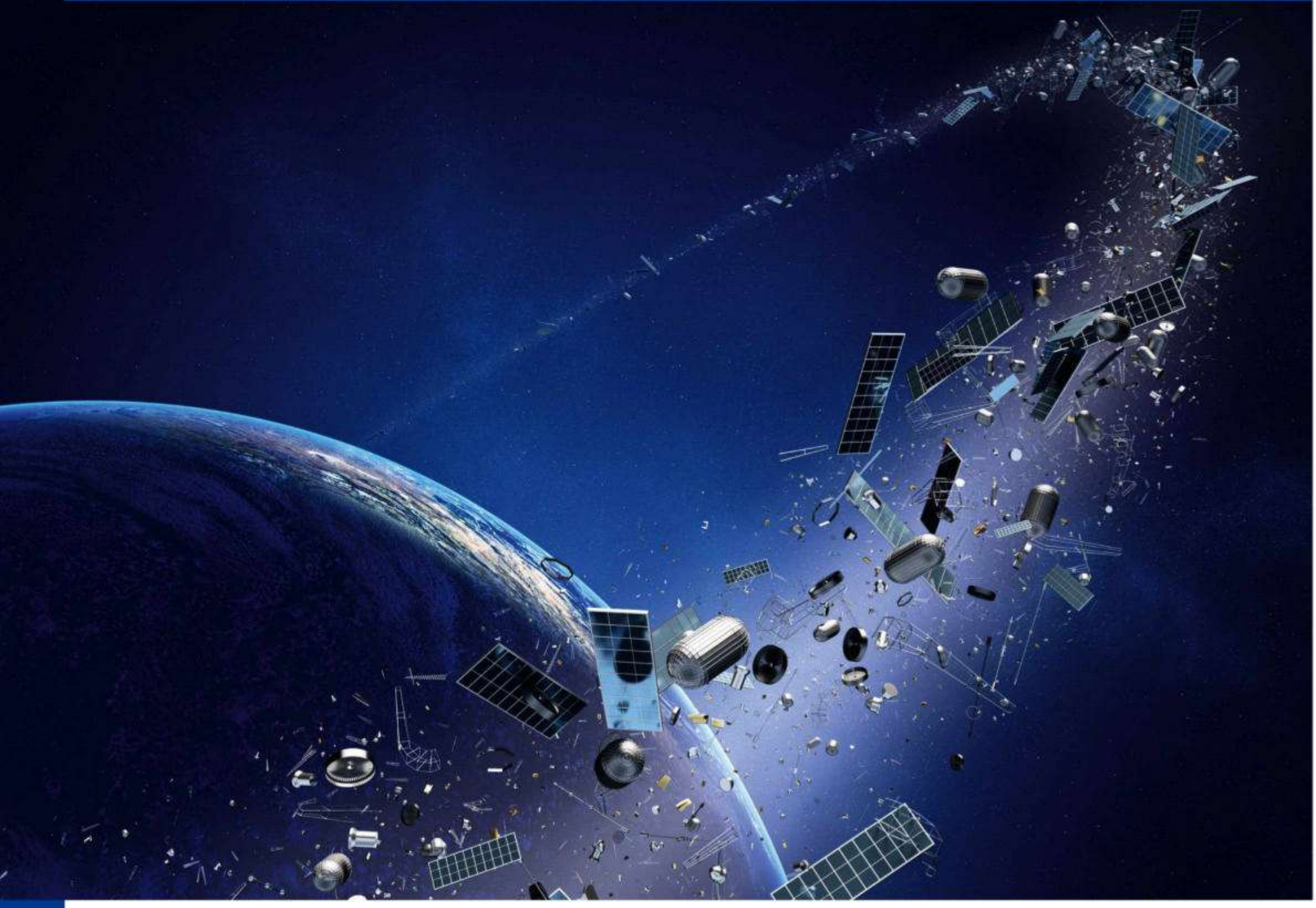
REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Space junk | Billionaires in space | Athletes and mental health



REVIEW

SPACE JUNK: IS IT A DISASTER WAITING TO HAPPEN?

Many experts are calling for urgent action before debris floating in orbit around the Earth triggers the domino-like Kessler syndrome

"Estimates suggest there are currently half a million pieces of debris the size of a marble or larger, and 100 million pieces of debris more than one millimetre across"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

This year, in May, a hole was found in a robotic arm aboard the International Space Station (ISS). The suspected culprit was a piece of space junk. While thankfully no astronauts were injured, it has re-focused attention on the growing problem of orbital debris.

HOW DID WE GET HERE?

It's easy to forget that just seven decades ago the Moon was the only thing orbiting the Earth. On 1 January 2021 there were 6,542 satellites in orbit. Tellingly, only just over half of them were active. That's a lot of useless metal careering around the planet at 28,000km/h – 10 times faster than a bullet. Jan Wörner, the former director general of the European Space Agency (ESA), put it this way: "Imagine how dangerous sailing the high seas would be if all the ships ever lost in history were still drifting on top of the water."

Even the smallest fragments, including stray nuts and bolts, and frozen particles of rocket fuel, can still cause immense amounts of damage. Even flecks of paint are a threat – they forced NASA to replace several damaged windows in the old Space Shuttle. According to NASA, millimetre-sized orbital debris represents the highest mission-ending risk to most robotic spacecraft operating in low Earth orbit.

HOW BAD IS THE PROBLEM?

It's very bad and getting worse. Estimates suggest there are currently half a million pieces of debris the size of a marble or larger, and 100 million pieces of debris more than one millimetre across. Yet only 27,000 pieces are actively tracked by the US Department of Defense.

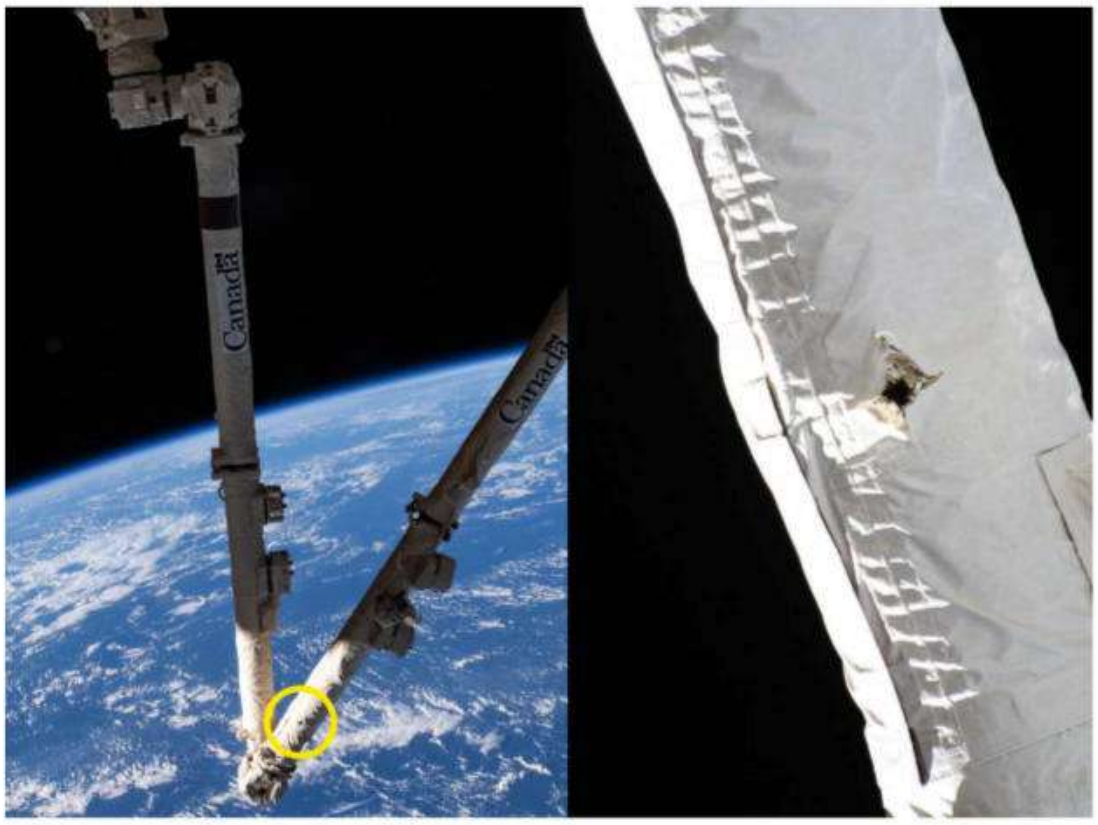
The ISS has had to conduct 29 debris avoidance manoeuvres since 1999, including three in 2020 alone. It doesn't help that some countries have decided to deliberately blow up their satellites with missiles as part of military test manoeuvres. Such a move by India in 2019 produced 400 shards of space debris.

Space is only going to get more crowded, with the number of satellite launches set to quintuple in the next decade. In January 2021, 143 satellites were launched into space on a single SpaceX Falcon rocket alone. SpaceX's satellite internet venture – Starlink – wants to put 12,000 satellites in orbit over the next five years. All this additional hardware significantly ramps up the chances of collisions and the dreaded Kessler syndrome.

WHAT IS KESSLER SYNDROME?

Kessler syndrome is a catastrophic chain of events in which a satellite is shattered by a piece of space junk (or a collision with another satellite) and the resulting debris destroys more satellites creating more junk and so on in a neverending cascade. It's a domino effect – one piece falls and then takes the rest with it – and is named after the NASA scientist Donald Kessler who outlined the dangers back in 1978.

According to a 2020 Space Sustainability report by the Organisation for Economic Co-operation and Development (OECD), Kessler syndrome has the potential to render certain orbits unusable for human activities. The report states that ▶



GETTY IMAGE, CANADIAN SPACE AGENCY/GOVERNMENT OF CANADA

BELOW LEFT Circled in yellow is the hole that was punctured in a robotic arm on the ISS by a piece of space junk

BELOW RIGHT Close-up of the small hole, where the extent of the damage can be seen

internet, weather and communication services are the most likely to be disrupted.

HOW CLOSE ARE WE TO TRIGGERING KESSLER SYNDROME?

A UN report from 2013 projected that catastrophic collisions may occur once every five to nine years over the next two centuries. It's already happening. In 2009 an Iridium communications satellite collided with the derelict Russian Kosmos 2251 satellite, destroying both spacecraft. That event happened at about the same altitude as one of the biggest dangers: the eight-tonne Earth observation satellite Envisat. Envisat will remain in orbit for the next 150 years and there's a 15 to 30 per cent chance that it will collide with a piece of space junk in that time. Kessler syndrome doesn't necessarily have to play out quickly. These impacts could be the first domino, with crashes ramping up significantly over time.

WHAT CAN WE DO ABOUT IT?

Better regulation of new launches would help, as right now it's a bit of a free-for-all. There are existing regulations in place to try and mitigate the dangers, such as a 25-year de-orbit rule for missions in low-Earth orbit. However, ESA's Space Debris Environment Report says that less than 60 per cent of those flying in low-Earth orbit currently stick to the rules. Penalties for rule-breakers should be stiffer. Deliberately blowing up satellites needs to stop. Increased monitoring of existing space junk helps because active satellites can be moved off a collision course by firing small thrusters. Yet dead satellites are sitting ducks and there's nothing we can do to avert a collision. That's why many are calling for a clean-up job. In 2018, the British-built RemoveDEBRIS mission tested a space junk harpoon in orbit. Meanwhile, ESA has commissioned the world's first space debris removal mission. Called ClearSpace-1, it will launch in 2025 and attempt to de-orbit the upper stage of a rocket left in space back in 2013.

by COLIN STUART (@skyponderer)
Colin is an astronomy author and speaker. Get a free e-book at ***colinstuart.net/ebook***

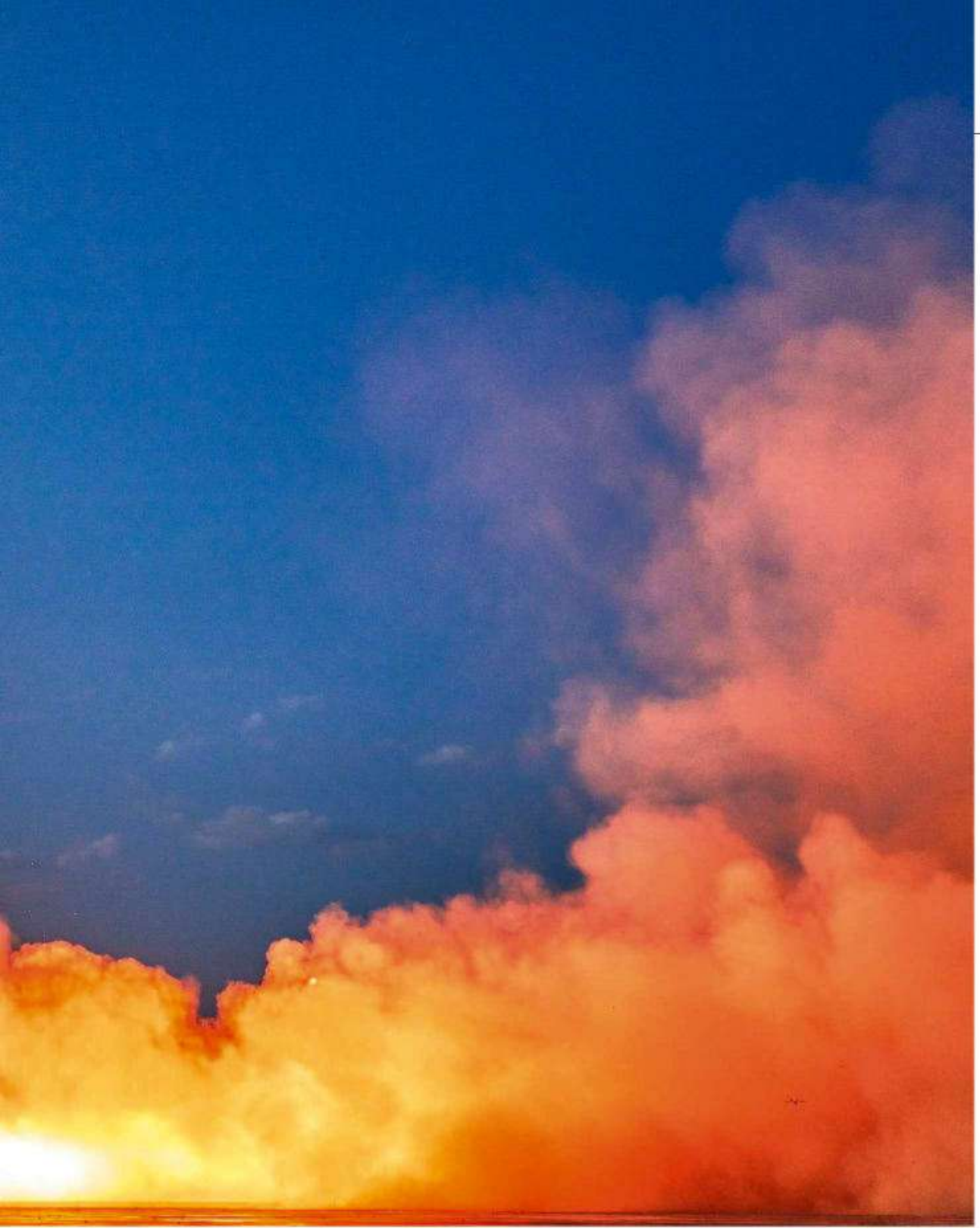
ANALYSIS

BILLIONAIRE SPACE RACE: WHAT DOES IT MEAN FOR THE CLIMATE?

New regulations regarding the environmental impacts from space travel must be put in place to prevent the emergence of a 'Wild West' attitude, experts say

Space travel made international headlines in July as both Amazon founder Jeff Bezos and Virgin boss Richard Branson flew to space in craft made by their own companies. Not to be outdone, Elon Musk's SpaceX plans to launch an all-civilian crew into orbit in September.

Commercial space travel is clearly firing up, and is predicted to become big business. Branson's Virgin



Galactic plans to begin regular commercial services in 2022, and already has 600 reservations at around $250,000 a ticket. According to a recent analysis from Swiss finance firm UBS, the space tourism industry will be worth $4bn by 2030.

Upon landing from his suborbital flight, Bezos said the experience reinforced his commitment to fighting climate change. But what impact could spaceflight have on the environment itself?

Rockets burn through huge amounts of propellants to take off. But there are a variety of ways to launch rockets into space, so understanding the exact impacts of each craft is not always straightforward.

"With all space travel, including space tourism, the environmental impacts depend on a variety of factors that are specific to the mission," says Dr Simit Raval, a senior lecturer at the University of New South Wales and co-author of a recent analysis on space launch emissions. More research is needed to ensure a "robust understanding" of these impacts, he says.

Arguably, the two most important environmental impacts of space travel are its contribution to global warming and stratospheric ozone loss, says Raval.

According to one estimate by Dr Eloise Marais at University College London, carbon dioxide emissions

ABOVE Jeff Bezos's Blue Origin craft hit headlines when it lifted off in July

SHUTTERSTOCK

"Space exploration ignores all of us who will be left behind to suffer the consequences of an overheated Earth"

for the four or so tourists on a space flight will be up to 100 times more than the emissions per passenger on a long-haul aeroplane flight – already a carbon-intensive activity.

According to a study at the University of New South Wales, alumina particles, black carbon and even water vapour released into the stratosphere are further causes for concern when it comes to global warming. However, the overall impact is complex as some of these emissions, such as soot, can also have a cooling effect.

Paul Peeters, an associate professor in sustainable transport and tourism at Breda University of Applied Sciences in the Netherlands, says that impacts could soon add up if space tourism becomes more common. "Launches into space each have significant ecological footprints per launch," he says.

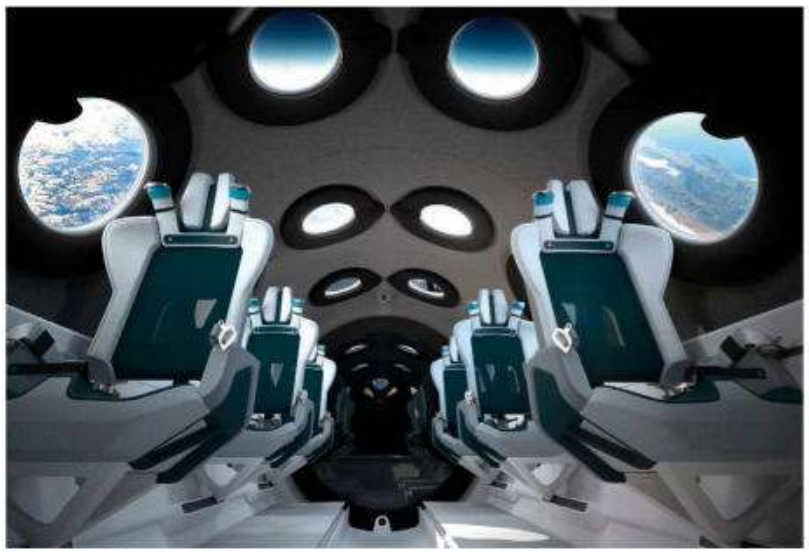
When it comes to climate change, much depends on the propellant, says Peeters. For example, hybrid rocket engines, which were used on Virgin Galactic's SpaceShipTwo, run on both solid and liquid fuel and release far more black carbon than kerosene fuel. "If hybrid rockets, which are assumed to be relatively cheap to operate, become popular, a climate disaster is looming," says Peeters.

Additional carbon emissions could also come from building spaceports, as well as from the space tourists flying to launch sites, possibly using private jets, says Annette Toivonen, tourism lecturer at Haaga-Helia University of Applied Sciences in Finland.

Alongside the climate impact, rocket launch exhaust plumes contain other substances which can deplete the Earth's ozone layer, such as nitrogen oxides, hydroxyl radicals and water. Emissions from space launches are not yet specifically addressed in the international Montreal Protocol, which addresses substances that deplete the ozone layer.

There can also be local pollution impacts at launch sites. For example, the long term use of unsymmetrical dimethylhydrazine (UDMH) rocket propellant at the Baikonur Cosmodrome spaceport in Kazakhstan led to severe environmental damage.

There are currently no global regulations or agreements regarding pollution or other environmental ➤



Virgin claims its spacecraft's cabin is designed for the "astronaut experience" with individual seats for g-force management

impacts from space travel.

"The current rise in private new space activities has created an increased demand to avoid a 'Wild West' attitude and ownership," says Toivonen. New types of regulations and legislative frameworks are needed, she says, including globally binding space-tourism legislation.

The US billionaires pushing space tourism claim that they offer hope and even future positive consequences for people around the world. Bezos has argued that space travel will help children "build a future", while Branson has said that private space travel will be "open to everyone".

Private space launches have certainly piqued the interest of many people. An analysis by Media Matters for America found that broadcast morning television in the US spent nearly as much time on the July Bezos space launch in one day as on the entire climate crisis in the whole of 2020. However, Evlondo Cooper, senior writer for Media Matters, says Bezos's space flight was a missed opportunity to cover both issues.

"Space exploration is exciting; but the undue attention given to those who can leave our planet too often ignores all of us who will be left behind to suffer the consequences of an overheated Earth driven by our world's polluting industries," he says.

Bezos has even argued that "all polluting industry" should be moved into space to keep Earth clean. But transporting heavy industry into space and then shipping the products back to Earth would require massive use of energy and resources.

While space travel will have the potential to become more energy-efficient or greener, it will still add to the environmental pressure on our planet without improving the quality of human life, argues Peeters.

The best decision, he says, would be to agree internationally that commercial space travel is "not a wise development" due to the current ongoing environmental and health crises.

—

by **JOCELYN TIMPERLEY**

Jocelyn is a freelance climate journalist, based in Costa Rica.

COMMENT

MENTAL HEALTH: HOW CAN WE HELP ELITE SPORTS COMPETITORS STAY WELL?

Elite Olympic athletes recently highlighted the mental health issues they faced. A psychologist explains how we could help them

Recently, mental health in sports was thrust into the public spotlight when Olympic gymnast Simone Biles and tennis star Naomi Osaka both chose not to compete, citing concerns over their mental wellbeing due to the pressures of elite competition.

Both athletes strongly expressed concerns over the ongoing effects of being in an intense competitive environment, and both argued that a deterioration in mental health is a legitimate reason for withdrawing from competition.

Although some reporters have been less than sympathetic, arguing that these highly paid athletes should accept and deal with the pressure, we should not be so easy to dismiss the notion that elite sportspeople need support for their mental health. After all, regardless of their talents, athletes are human beings just like the rest of us, and being able to play sport at an elite level does not provide immunity to poor mental health.

Some commentators have said that the two athletes simply lack mental toughness. But arguably, withdrawing from such high-profile competition after years of training and preparation was a more difficult decision to make than to go ahead and compete. Moreover, if they had cited a physical injury, such as an injured knee, their withdrawal would not even be questioned.

So why are elite sportspeople under so much pressure, and how can we learn from this experience to provide better mental health provision?

To do this it is important to understand the factors that make elite sporting competition such a highly pressured environment. First, competitions are won and lost in mere moments. Consider a gymnast with their sights set on Olympic gold, for example. One slip, or one lapse of concentration, and that ambition is gone in an instant.

Athletes spend years training to perform to the best of their abilities in that one specific moment. When you add to that the fact that they are representing an entire country, and that they feel that the focus of thousands, including their family and friends, is

GETTY IMAGES, SHUTTERSTOCK

"Consider a gymnast with their sights set on Olympic gold, for example. One slip, or one lapse of concentration, and that ambition is gone in an instant"

on their performance, this generates a huge sense of pressure.

So, elite athletes experience intense emotions surrounding competition, and some of these are likely to be unpleasant emotions such as anxiety over the uncertainty of the outcome, and possibly guilt, shame and misery if they anticipate not performing at their best.

A team of international researchers recently carried out a systematic review of 600 studies comparing athletes' performance to their scores in a commonly used mood-profiling test designed to assess a person's relative levels of anger, confusion, depression, fatigue, tension and vigour. They found that poor mental health and poor sporting performance were both linked to high scores on unpleasant mood states and low scores for vigour. As such, mood profiling is one potential strategy for managing athletes' mental health.

Emotions experienced before and during sporting competition also have a significant effect on athletes' performance in everything from interacting with teammates to improving their economy of movement. The regulation of emotions is therefore regarded as an important skill by sports psychologists.

When it comes to describing how athletes can regulate emotions, sports psychologists have developed a theoretical model based on five strategies: situation selection, situation modification, attention deployment, cognitive change, and response modulation.

Situation selection is the process by which an athlete actively chooses to place themselves in one situation rather than another, while situation modification refers to attempts to modify external aspects of the environment. By doing either of these things, an athlete can make it more likely that a desirable emotional state is attained, or an undesirable one is avoided.

Attention deployment is the process whereby an athlete directs their attention away from things that could have a negative impact on their emotions. One example would be listening to music on headphones to avoid hearing the crowd prior to an event.

Cognitive change involves the athlete consciously changing the meaning of an event. For example, a football player who has just missed a penalty may reappraise the extent of self-blame by saying, "It was a great shot, but an even better save by the keeper."

ABOVE Gymnast Simone Biles is consoled by her trainer after withdrawing from competition in the 2020 Olympics

Finally, response modulation refers to strategies designed to regulate the physiological and cognitive aspects of emotion as directly as possible. This could involve strategies such as progressive muscular relaxation or centring.

So, where does this leave us? We recognise that elite athletes are prone to experiencing deterioration in mental health and therefore it is important that we provide support. Developing interventions that help athletes improve their ability to regulate their emotions should be a key part of training programmes, with the aim of helping them take care of their mental health. This is opposed to an approach where we simply wait for athletes to develop mental health issues and then treat the effects. Prevention is better than cure, and positive mental health should be the prize that all athletes strive for. **SF**

by **PROF ANDREW LANE**

Andrew is a sports psychologist based at the University of Wolverhampton where he is director of research excellence and associate dean in the Faculty of Education, Health and Wellbeing.

Unleash your inner biker, eco-friendly style! p41

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

The chainmail-like material can behave fluidly or rigidly

CLIMATE-ACTIVE TEXTILES

Researchers in MIT's Self-Assembly Lab have created 'climate-active' textiles. Seemingly built for the UK's indecisive weather, the materials respond to temperature changes by contracting in the cold to close up gaps in the fabric, then relaxing in the heat to breathe.

4D PRINTING

4D printing is what happens when you add materials to 3D printing that change shape in the presence of water or heat. It means you could, for example, create pipes that expand when it's cold to avoid ice creating a crack.

ADJUSTABLE WINGS

Carbon fibre that changes shape when exposed to heat or water creates a strong material that can respond to the environment. One street legal race car has a rear wing that opens or closes depending on the rain, creating more downforce when it's wet to improve traction to the rear tyres.

MATERIALS

Smart chainmail switches from tough to flexible on command

Engineers say new fabric could pave the way for adaptive exoskeletons or casts for broken bones

In the Batman movies, the Dark Knight's cape pulls off a neat trick. Most of the time it billows behind him while he crumples nameless henchmen, but when Batman needs to make a quick escape, he can leap off a building and stiffen his cape so that it works like a glider that carries him into the night. One moment the cape is fluid, then the next it's rigid. It's a neat trick that engineers at Caltech and JPL have now replicated in the real world.

This material, inspired by chainmail, can go from a foldable, fluid-like state into a specific solid shape with the application of pressure. The researchers behind it hope this tech could potentially be used as a smart fabric for exoskeletons, or even as an adaptive cast to be applied to a broken limb, to keep your bones where they need to be.

"IN ONE DEMONSTRATION, THE FABRIC COULD SUPPORT A LOAD MORE THAN 50 TIMES ITS WEIGHT"

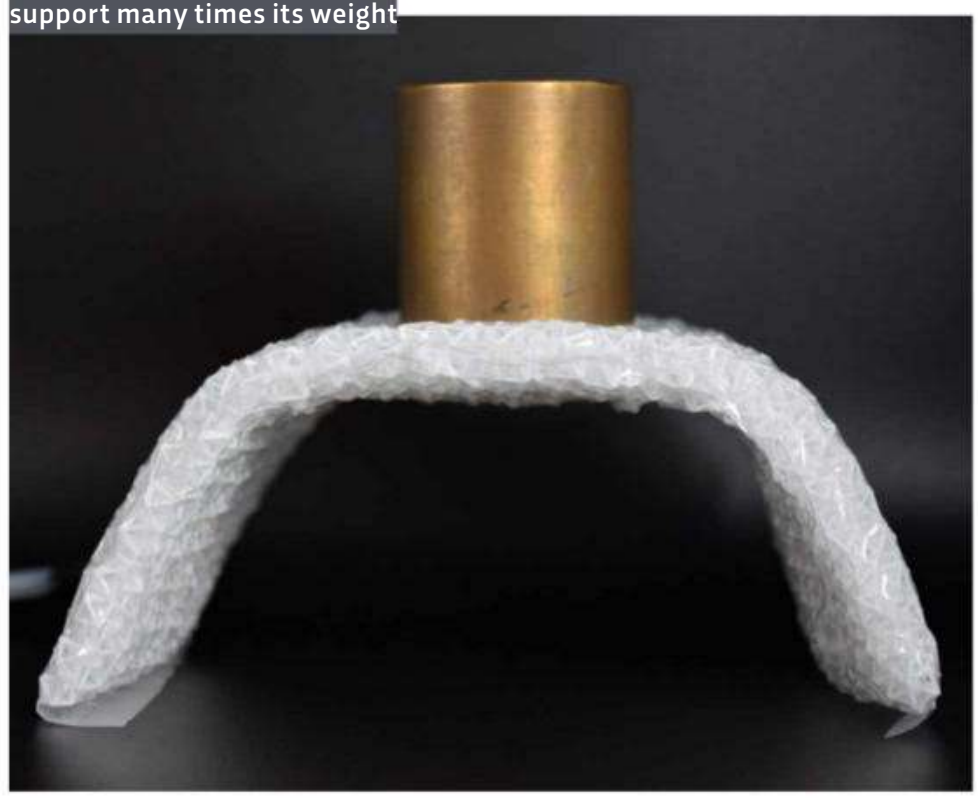
CALTECH X2, MIT X2, CARMEL SNOW

The physics behind the technology will be familiar to anyone's who's bought vacuum-packed coffee, explains Chiara Daraio, a professor of mechanical engineering and applied physics at Caltech. "Think about coffee in a vacuum-sealed bag. When still packed, it is solid, via a process we call 'jamming'. But as soon as you open the package, the coffee grounds are no longer jammed against each other and you can pour them as though they were a fluid," she says.

To discover the chainmail that would be the most flexible at rest and the stiffest under pressure, the team 3D-printed different configurations of linked particles and tested each in a computer simulation. They discovered that the larger the average number of contacts between particles – such has rings or squares – the greater the difference between how flexible and how stiff the material could become. In one demonstration, the fabric was able to support a load more than 50 times its own weight.

In parallel research, Daraio and her team are investigating strips of polymers that shrink when heated. These strips could be woven into this new type of chainmail to create solid objects – like bridges – that fold down flat when not needed. The two materials working together could also, she suggests, create robots that can morph into different shapes to solve different problems.

↘ When rigid, the material can support many times its weight



INTERVIEW

What's it like to fly to the edge of space?

Dave Mackay, Virgin Galactic's chief pilot, reveals what it's like to ride a rocket ship to the stars...

Unless you have six figures of spare change sitting in an ISA, chances are you won't be joining the next generation of space tourists any time soon. This summer, Amazon founder Jeff Bezos briefly left the planet on his Blue Origin spacecraft, and before him, Virgin's Richard Branson fulfilled a decades-old promise to himself by flying aboard *VSS Unity* beyond the Earth's atmosphere.

Whatever your view of the billionaire space race, there's one question we all have: what's it really like? One person uniquely qualified to describe the experience is David Mackay, chief pilot at Virgin Galactic. The former RAF test pilot was in the pilot's seat for Branson's trip in July, which marked the third time that he himself had flown into low-Earth orbit. Here, the first native-born Scot to leave our atmosphere takes us on a trip into low-Earth orbit.

TELL US WHAT IT'S LIKE WHEN YOU RELEASE FROM THE MOTHERSHIP AT ALTITUDE AND THAT ROCKET FIRES.

That's when the vehicle comes alive. There's no punch in the back. It just comes on and runs up to very high acceleration, about 3g longitudinal acceleration, which is hard for people to understand. It's smooth. It's not very loud, because of course you're leaving a lot of the sound behind you. In about eight seconds you go supersonic and you end up over Mach 3. At the end of boost, we pitch up vertically and then you're pointing straight up, still with this amazing acceleration – but again it's extremely smooth. And then you find yourself weightless.

WHAT'S THE BEST VIEW?

In the cabin you have windows at the side, and you also have another window up above you. We believe the best view is in the inverted position. The windows let you look up or down, so you can see down to Earth where you've come from, you can see the planet racing away from you. You can also look out sideways and see that dense blackness of space. There's this beautiful, thin band of the atmosphere around the planet.

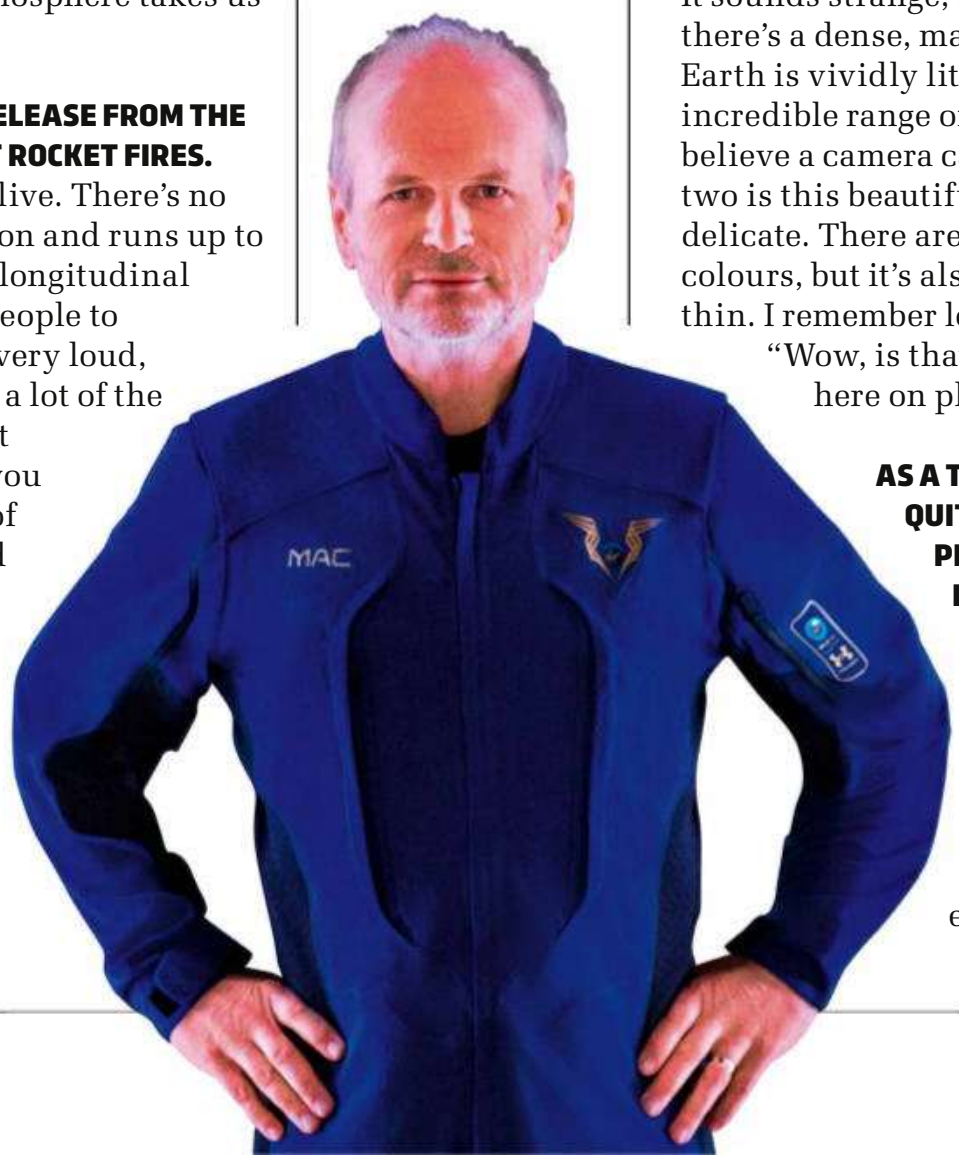
ASTRONAUTS OFTEN SAY THAT BEING UP THERE CHANGES THEM IN SOME WAY. THERE'S SOME KIND OF SPIRITUAL OR ENVIRONMENTAL AWAKENING. WAS THAT THE CASE FOR YOU?

It's interesting. Lots of people ask that question and my initial reaction afterwards was, "No, I'm the same Dave Mackay I always was." But actually, I think it does. It has an effect that kind of builds over days and weeks and months afterwards when you reflect on what you've done and what you've seen. The initial reaction when you're out there is just: wow.

CAN YOU DESCRIBE THE VIEW?

It sounds strange, but space is blacker than black: there's a dense, matte black and in contrast, the Earth is vividly lit, very, very bright. There's this incredible range of brightness, which I don't believe a camera can ever capture. In between the two is this beautiful atmosphere, which is very delicate. There are lots of different layers and colours, but it's also thin – kind of worryingly thin. I remember looking at that and thinking, "Wow, is that what's keeping us all alive here on planet Earth?"

↓ Dave Mackay, Virgin Galactic's chief pilot



VIRGIN GALACTIC X2

AS A TEST PILOT, I ASSUME YOU'RE QUITE AN ANALYTICAL, TECHNICAL PERSON. WHEN YOU'RE UP THERE, DO YOU GET TO APPRECIATE THE BEAUTY OF IT OR ALLOW ANY EMOTION TO SEEP IN? OR IS IT YOUR JOB NOT TO DO THAT?

Yeah, a lot of the job is hard work, we're trying to gather a lot of information in a short space of time, trying to be as efficient as possible because

↑ Inside the Virgin Galactic cockpit

every test flight is expensive and takes weeks, months, sometimes years of planning and preparation. We're in the simulator every day, sometimes twice a day, working really hard to try and do the job as best we can. But once you leave the atmosphere and you've put the vehicle in the altitude desired, there is this period of time where you're sitting there with no forces on your body, the vehicle is sort of doing its own thing. There's no motion, no forces, no sound because we don't have any fans or anything running at that time. And if everything's normal, which 99.9 times out of 100 it is, then you do have a few seconds to look out of the window.

HOW DOES RE-ENTRY FEEL?

Initially it's absolute quietness and then you start to hear this noise outside. I've heard people say you can hear individual air molecules hitting the underside of the vehicle. I'm not sure that's true, but as we accelerate down and the atmosphere is getting much thicker, it builds to this crescendo which sounds almost like a waterfall hitting the underside of the vehicle. It's quite amazing. I like that because it kind of emphasises that you've been to somewhere special and now you're returning to the Earth. There's a little bit of rocking and rolling and some high vibration, but it's really comfortable. Then around 80,000ft [24,384m approx] we become subsonic again and then around about 50,000ft [15,240m approx] we lower the feather [a structure on the wing] and then we're gliding, without an engine.

THIS KIND OF TRIP IS WONDERFUL FOR THE PASSENGERS, BUT WHAT'S IN IT FOR THE REST OF US? WHAT'S THE BROADER BENEFIT OF THIS?

Well, the individual experience is certainly remarkable and I think that will have a profound effect on people's minds. You will return to Earth with a better appreciation of the planet's remoteness in the big scheme of things because you look out into this blackness of space and there's just nothing else there.

There's also a lot of valuable science that can be done in space. We recently flew experiments into space with gaps of six weeks and that hasn't been possible in the past. The other thing is, the times we're living in now, this is kind of the Apollo moment from my youth. I watched the Apollo Moon landings and that was an inspiration to me and hundreds of thousands, if not millions of people around the world. Hopefully, this will inspire a whole new generation of young people to get involved in engineering or science.

Ideas we like...

↓...noise-cancelling earbuds that don't cost the Earth

These new wireless earbuds are the most hyped new product in tech right now. Backed by the likes of Tony Fadell, who invented the iPod, and Casey Neistat, one of YouTube's most revered vloggers, there's a huge amount of buzz surrounding this product that aims to bring premium audio performance at a wallet-friendly price bracket. It's something that the company's CEO Carl Pei had a track record for at his previous mobile phone company, OnePlus, which specialised in unfussy smartphones with powerful chipsets. We can't vouch for the sound yet, but we love the design and retro-futurism aesthetic. For the price, there's an impressive set of features, including variable levels of noise cancellation, water- and splash-resistance and customisable gesture controls on the earbuds themselves.

Nothing Ear
£99, nothing.tech

↑...a foldable phone that works

This is the first foldable phone that might be worth a go. The first few iterations of foldables were marred with reliability issues and huge price tags. However at £949, this phone is likely to cost as much on contract as the latest Apple or Google devices. There's no sacrificing on processing power or features to make the phone work at this price either: the Flip3 comes with an octa-core processor inside, plenty of RAM and a 120Hz display. Plus it's waterproof. Folding the phone will split the display in two, so you can, for example, sit the phone on the table to watch videos. There's also a small screen on the back so that you can see notifications when your phone is shut. We'd give it a few months to see if anyone reports any hardware issues with the screen, but we personally can't wait to see what they do with foldable tablets next…

Samsung Galaxy Z Flip3
From £949, samsung.com

→...an affordable travel drone

The DJI Mini SE crams in an unbelievable amount of tech into a tiny package. It's just 14cm long and 8cm wide, and is light enough at 249g to be allowed in your hand luggage if you're travelling. Inside the shell there's a 2.7k resolution camera with a gimbal that will keep your footage steady. There's a generous 30-minute flight time and a 4km HD video transmission range. This is the cheapest DJI model to date, and it's aimed squarely at inviting newcomers to make a massive upgrade to their travel photography as things return to normal.

DJI Mini SE
$299 (£256 approx), dji.com

←...a new kind of surround sound system

Sony's new speaker system is designed for those that want to get serious home cinema surround sound, without having to spend time and effort draping wires around your living room. The HT-A9 system is essentially a set of four wireless speakers that talk to a control box plugged directly into your TV. You just place the four speakers around you, and let the setup – which echolocates each speaker – calibrate to you and your living room. Each device has a tweeter, a sub and an upfiring speaker to power the full Dolby Atmos experience. Pair these with a Sony TV and the system will also use your TV's speakers to add to the sound.

Sony HT-A9
From £1,600, sony.co.uk

↓ ...smart-looking electric bikes

As city centres start to kick out fossil-fuel burning vehicles to reduce air pollution, electric bikes increasingly look like the best commuter option for those of us who don't want to slip into some Lycra. Plus, would you look at this bike! The DAB Concept-E is the electric equivalent of a 125cc motorbike, which you can ride after a few hours of training and a thorough read of the Highway Code. The bike is reported to have a range of about 112km (70 miles) and it tops out at 104km/h (65mph). Sadly, it's just a concept right now, with no price, but this is one of a new wave of very cool looking e-bikes on the way.

DAB Motors Concept-E
£TBC, dabmotors.com

↑ ...a mouse for sweaty gamers

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FASTER THAN THE SPEED OF SOUND

CONCORDE FLEW FROM LONDON TO NEW YORK IN THREE AND A HALF HOURS. IT SOARED AT NEARLY TWICE THE SPEED OF SOUND, LEAVING AN ALMIGHTY SONIC BOOM IN ITS WAKE. THE NOISE RESTRICTED WHERE IT COULD FLY, BUT NOW NASA HOPES IT CAN RESURRECT FASTER-THAN-SOUND TRAVEL, WITH QUIET SUPERSONIC FLIGHT

WORDS: **ANDREW MAY**

LOCKHEED MARTIN

NASA, perhaps best known for its spacecraft, also has pretty sizeable fleet of aircraft under its belt. It has a venerable tradition of X-planes, where 'X' stands for experimental. It started back in 1946 with the X-1, which became the first aircraft to travel faster than sound. Three-quarters of a century on, its new plane, the X-59, also aims to break the sound barrier – but this time it's going to do it quietly.

The speed of sound has always caused headaches for aircraft designers. The reason lies in the nature of sound itself. When anything from a handclap to a rocket disturbs the air, it causes pressure changes that spread out like a wave. The speed of this wave depends on the properties of the air, but under normal conditions it's around 1,200km/h (750mph).

"All aircraft change the pressure in the air around them as they fly," explains Peter Coen of NASA's Langley Research Center. The consequences depend on whether the aircraft is flying slower or faster than the sound it produces. "In a typical subsonic aircraft, the pressure changes are gradual, [so] air molecules ahead of the aircraft sense the pressure change before the aircraft reaches them," Coen continues. "But if an airplane flies faster than sound, the molecules upstream don't know that it is coming."

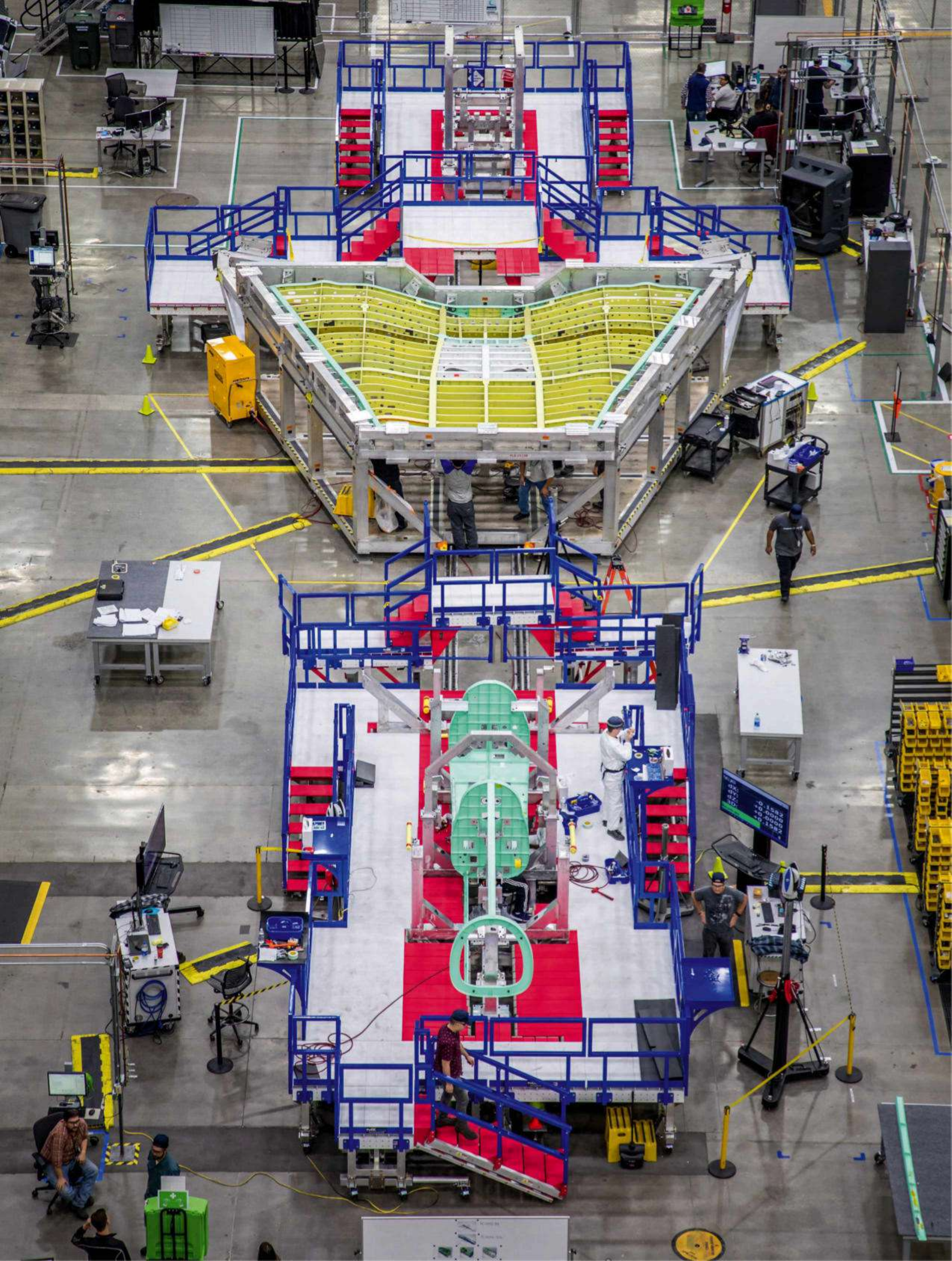
From the point of view of those molecules, all the sound waves the aircraft has been pushing ahead of it arrive at once. "The pressure changes happen instantaneously in what is called a shock wave," Coen says. "A shock wave, from the nose of the aircraft for example, travels outward in all directions and merges with other shocks, from the wings or cockpit window... The result of this is two large, distinct shock waves that we hear on the ground as the two booms of a sonic boom."

"IF AN AIRPLANE FLIES FASTER THAN SOUND, THE MOLECULES UPSTREAM DON'T KNOW THAT IT IS COMING"

ABOVE At Lockheed Martin's Skunk Works factory in Palmdale, California, an engineer works on the fuselage section of the X-59. The black rectangular panels are air intakes for the plane's environmental control system (ECS), and the silver grate is the ECS exhaust. These features are placed on the top of the craft to reshape the shock wave pattern

RIGHT The general shape of the X-59, including the wings, can be seen here as the craft is assembled

LOCKHEED MARTIN X2



While we may only hear the sonic boom briefly, it's actually produced continuously for as long as the aircraft is supersonic. People at different points under the flight path will hear it at different times – and when they do, they'll all jump out of their skin in surprise. That's why, back in the 1970s, the United States and many other countries imposed an almost complete ban on supersonic flight over their territories.

This situation is unlikely to change unless the sonic boom is reduced to an acceptable level. This is where Coen and his team come in. He's the mission integration manager for NASA's Low-Boom Flight Demonstration project. Their aim is to produce a viable supersonic design that's no more disruptive to people on the ground than an ordinary aircraft. That would've been unthinkable 50 years ago, but advances in computer-aided design mean it's within our grasp today. The result, a collaborative effort with Lockheed Martin, is the X-59 – a proposed test vehicle dubbed QueSST (for Quiet Supersonic Technology).

"The X-59 aircraft is equipped with unique shaping and supersonic technologies," Coen explains. "A long slender nose, engine placement on the top of the aircraft and its External Vision System are all designed to control the strength and position of the shock waves to produce a softer sound to those on the ground."

The aim isn't to eliminate shock waves altogether – which is impossible – but to design the aircraft in such a way that the shock waves are spaced roughly equally along its length. "Because of this, the shock waves do not merge into the double shock boom but are individually weakened and softened," says Coen.

Although it was designed with aerodynamic considerations first and foremost, the X-59 is a

BELOW The F414-GE-100 engine sits in the assembly area at GE Aviation's Riverworks facility in Lynn, Massachusetts, as it prepares for checkout tests. The engine will power the X-59 in flight

striking-looking aircraft by any standards. Almost a third of its 30-metre length is taken up by the sharply pointed nose, behind which the single-seat cockpit is so carefully moulded into the streamlined fuselage that it's barely discernible. In fact, the pilot doesn't even have a forward-facing windscreen – just an HD video display showing the view ahead (that's the External Vision System that Coen referred to earlier).

All this careful shaping should, according to the simulations, reduce the dreaded sonic boom to a more acceptable 'sonic thump'. To quantify sudden, sharp sounds, NASA uses a measure called 'perceived level decibels', or PLdB. A conventional sonic boom is around 105PLdB, while a car door slamming six metres away is just 75PLdB. That's the level the X-59 is aiming at. When it's flying at 1,400km/h (925mph) – around 1.4 times the speed of sound – at a typical cruising altitude, all you should hear is a mild thump no worse than your neighbour slamming a car door.

So far, however, it's all theory. Only when NASA takes delivery of the X-59 from Lockheed Martin early in 2023 will they be able to see how reality measures up. The test schedule will fall into two phases – careful scientific measurements over NASA's California test ranges to start with,

"ALL THIS CAREFUL SHAPING SHOULD REDUCE THE SONIC BOOM TO A 'SONIC THUMP'"

followed by a community response study over a few selected US cities. The latter phase is crucial, because there are subtleties in the way people react to sounds that go beyond measurable quantities like PLdB. Coen and his team hope the X-59's sonic thump will be acceptable to the public, but they can't be sure. "Once we get into the community overflight test phase of the mission, we will collect this input from people who are actually on the ground and hear the sound the X-59 makes when it flies overhead," Coen explains.

Gauging public reaction is critical, because ultimately only this – as opposed to any number of scientific measurements and calculations – will carry weight with aviation regulators. The aim is to persuade them to modify the blanket ban on supersonic overflights, granting an exemption

ABOVE This image is looking inside the X-59's engine inlet. Usually, the engine is placed on the bottom of an aircraft, but on the X-59, this section of the inlet and engine are mounted to the top of the plane. This is so the shock waves from the inlet and engine are shielded by the wing to reduce the sonic boom to a sonic thump

GE AVIATION, LOCKHEED MARTIN

"THE FINAL YEARS OF THIS DECADE COULD SEE THE START OF A SECOND GREAT ERA OF SUPERSONIC AIR TRAVEL"

for any future aircraft that might pick up on the X-59's low-boom design features.

If everything goes the way NASA is hoping, the final years of this decade could see the start of a second great era of supersonic air travel, following the abortive first era that began and ended with Concorde. Operated between 1976 and 2003 by just two airlines, British Airways and Air France, the stringent flight restrictions meant the iconic aircraft was only ever used on transatlantic routes. Concorde was notoriously expensive, of course, but that was largely because it was the first of its kind. And with such a limited range of available routes, aerospace companies simply didn't have sufficient incentive to carry out the research that might have made it more economical in terms of fuel consumption and passenger capacity.

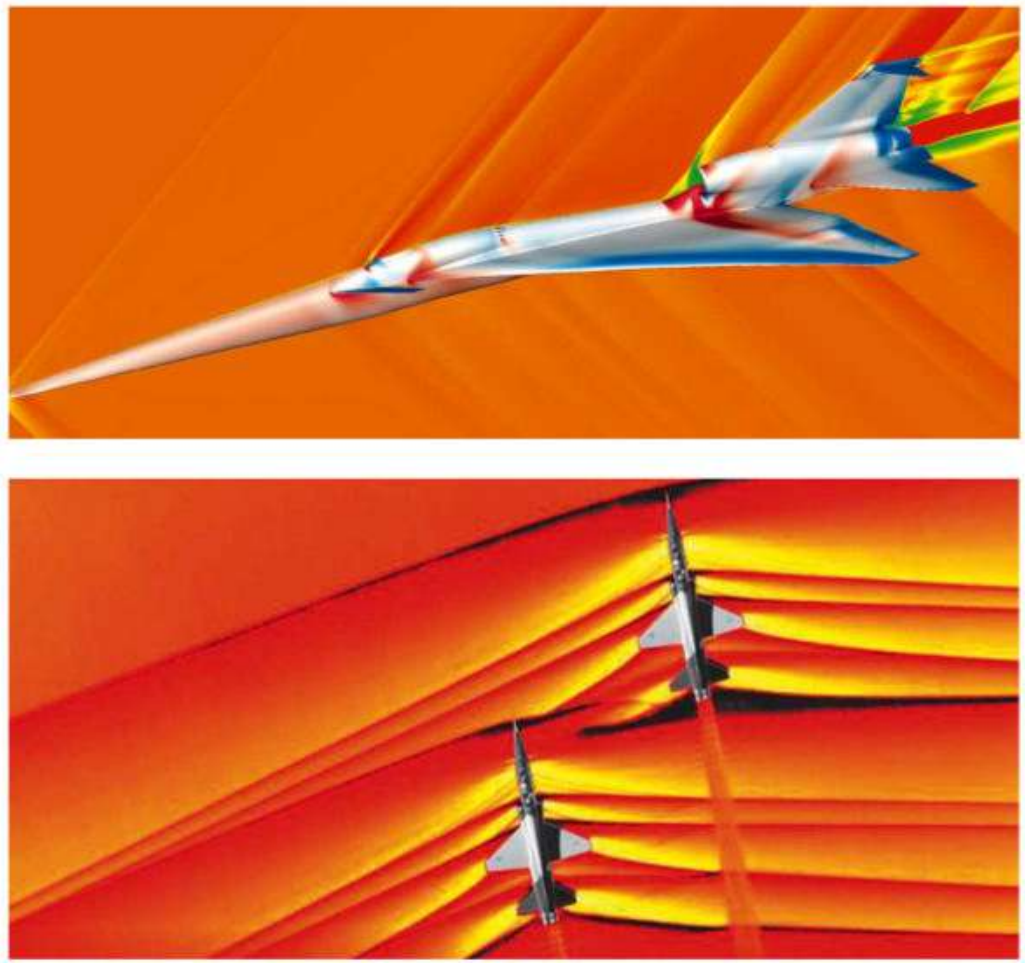
In an alternative timeline in which the sonic boom problem never arose, the situation today might have been very different, with supersonic air travel being the norm on all the world's long-haul routes. Now there's a real possibility that this could happen in our world, if the X-59 lives up to expectations. **SF**

ABOVE Illustration of how the completed X-59 might look

LEFT Rather than a forward-facing windscreen, the pilot sees the view via an HD video display

RIGHT The top image is a visualisation of the X-59 in supersonic flight to help determine which features of the craft are generating shock waves. The colours shown on the plane indicate surface pressure, (lower pressures in blue, higher pressures in red). The colours shown in the space surrounding the plane indicate airflow velocity, (zero velocity in blue, higher velocities in red). In comparison, in the bottom image, you can see the shock waves produced by two T-38 supersonic fighter jets

LOCKHEED MARTIN X2, NASA/JAMES C JENSEN, NASA/JPL



by **DR ANDREW MAY**
Andrew is a science, history and sci-fi writer, with a background in astrophysics.

BBC RADIO 4

Listen to Dr Helen Scales talking about marine conservation on *The Life Scientific*
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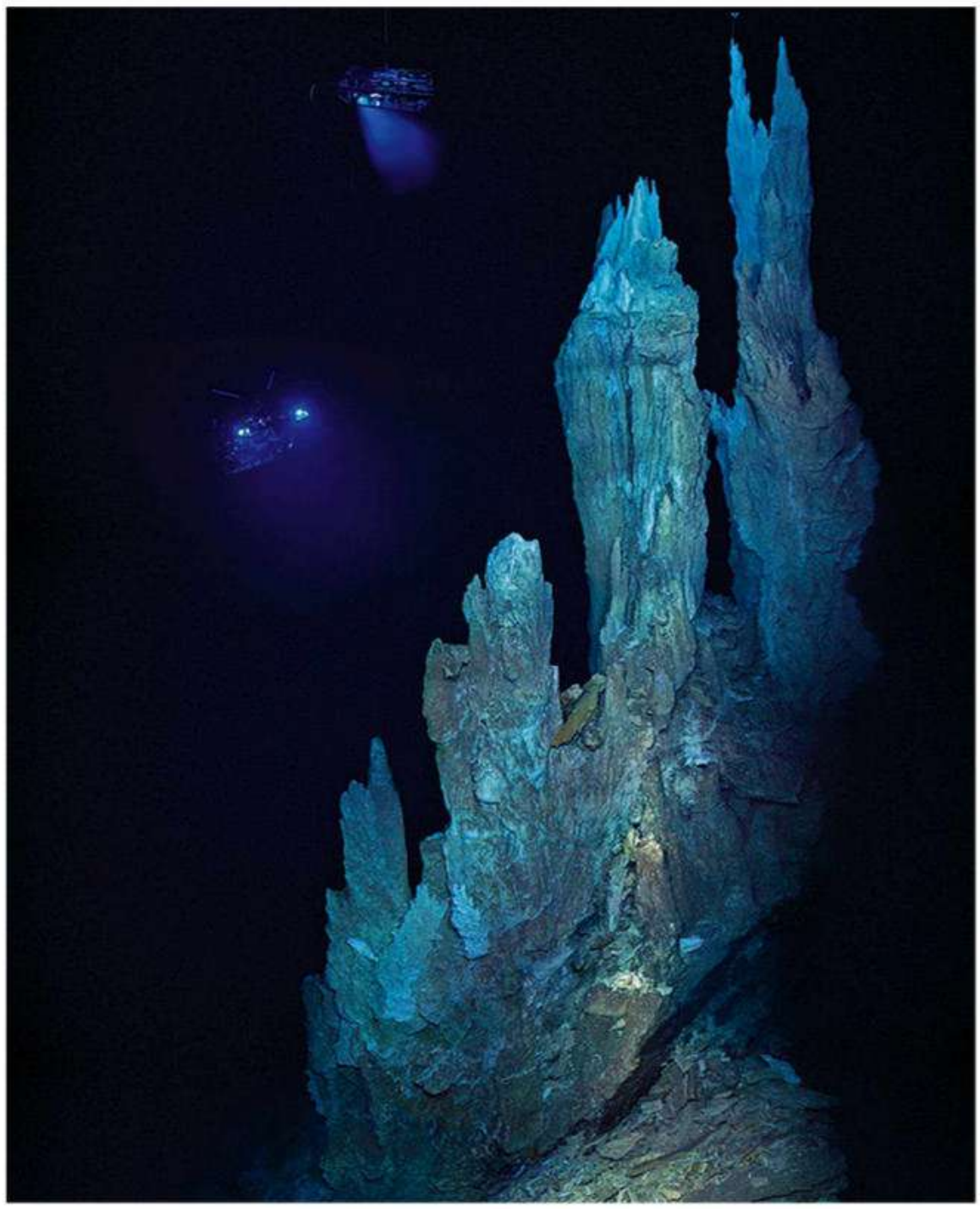
Fabien Cousteau's Proteus. Initial concept design by Yves Béhar and Fuseproject

MYSTERIES OF THE ABYSS

The deep sea is Earth's last unexplored domain. For the longest time, this enigmatic ecosystem has held within it answers to some of the most important questions in science. Now, a new wave of technologies are powering discoveries that will help us put together the story of Earth's final frontier

WORDS **DR HELEN SCALES**

1 DID LIFE BEGIN IN THE DEEP SEA?



Unlike most hydrothermal vents, The Lost City vents, located in the middle of the Atlantic Ocean, are alkaline. Life on Earth could have first emerged around these 'white smokers'

D KELLEY/M ELEND/UW/URI-IAO/NOAA, SCHMIDT OCEAN INSTITUTE

Life on Earth began about four billion years ago. Where and how those simple cells first sparked into life remain tantalising mysteries, but evidence is stacking up that they could have first emerged in the deep ocean.

In 2017, palaeontologists identified microscopic tubes and filaments made of iron-rich haematite lodged within rocks formed between 3.77 and 4.28 billion years ago. The rocks are a rare fragment of primeval oceanic crust preserved on land (most of the seafloor gets dragged back into the Earth's mantle, melted and recycled into new crust). The tiny formations have the characteristic shape of microbes that live today on deep-sea hydrothermal vents – the hot springs that form underwater at the edges of tectonic plates.

The fossil find lends support to a theory put forward in the 1990s by NASA chemist, Dr Michael Russell. His idea is that the templates for living cells were provided by tiny rocky pores inside the chimneys of hydrothermal vents. A specific set of circumstances would have been essential for this to happen, in particular the temperature can't have been too high or the first signs of life would have been immediately scorched. Also, the fluids pouring through these vents would have needed to be alkaline to set up the conditions that generate energy in all living cells today.

Most vents, known as black smokers, are blisteringly hot and strongly acidic. But one incredibly rare formation called The Lost City, located in the Atlantic Ocean, provides the right set of conditions. What's more, white smokers like this one are thought to have been much more common on the younger Earth. More clues that this could have been where life got going are coming from laboratories a long way from the abyss. In California, at NASA's Jet Propulsion Laboratory, space scientists Dr Laurie Barge and Erika Flores have been growing tiny hydrothermal vents and successfully generated amino acids, an important building block of life. Meanwhile, at University College London, Prof Nick Lane's team built a reactor to simulate the conditions of an alkaline hydrothermal vent, similar to The Lost City. They combined a mixture of fatty acids and fatty alcohols that spontaneously formed a membrane enclosing a drop of liquid – a basic proto-cell.

The theory of life originating in hydrothermal vents raises a thrilling possibility that life could begin elsewhere in the Solar System in a similar way. Scientists suspect there are hydrothermal vents on Saturn's moon Enceladus, and in the giant salty ocean that lies beneath an ice crust on Jupiter's moon Europa. NASA's Clipper mission may detect signs of a habitable ocean when it arrives in orbit around Jupiter and swings close to its icy moon in 2030.

2 HOW MANY UNDISCOVERED CREATURES LIVE IN THE DEEP?

One thing is clear: scientists aren't going to run out of new, deep-sea species to find any time soon. In a recent three-year study in the Pacific Ocean, remotely operated vehicles (ROVs) photographed nearly 350,000 animals: fish, octopuses, corals, anemones, shrimp, squid, sponges, and sculpted, living mud balls called xenophyophores... the list goes on. Only one in five were known species. Not all the images were clear enough to identify, but most were organisms nobody had seen before.

Whenever scientists look in the deep ocean they're pretty much guaranteed to find something new and unexpected. "It's always an incredible adventure," says Prof Randi Rotjan from Boston University, who just returned from co-leading a month-long expedition to the Phoenix archipelago in the central Pacific Ocean. Their mission on the Schmidt Ocean Institute's *RV Falkor* involved studying the ecosystems on seamounts. With the ROV *SuBastian*, the team conducted 21 dives and clocked up 250 hours underwater, gathering samples and high definition video of corals, sponges and other intricate life forms.

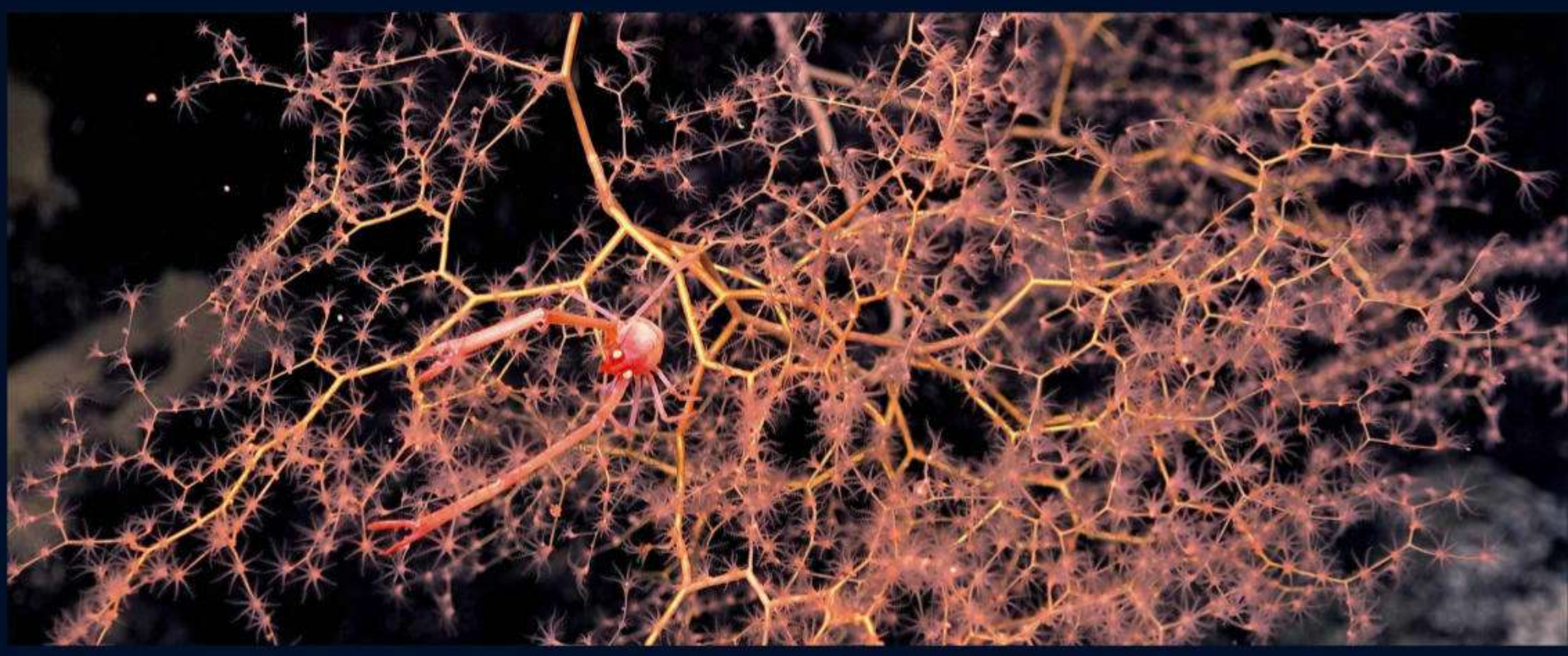
Standard techniques for studying deep-sea species involve a combination of visual recognition and collecting specimens for detailed analysis. Environmental DNA (eDNA), which looks for DNA-containing cells and mucus shed by organisms in large samples of water, is becoming a quicker and cheaper way of finding out which species are in the vicinity.

Archives of genetic sequences from deep-sea species are gradually being built. One day it should be possible to know whether a giant squid or a Greenland shark or any other mysterious deep-sea denizen just swam by out of sight, from the DNA they left behind.

When Rotjan's team have finished analysing their findings, they will undoubtedly be adding entries to the World Register of Deep-Sea Species, which in mid-2021 listed 26,599 species, a number that's rising all the time. "It's not just a catalogue of what's there, but why they're there, who they're interacting with and what they're doing," says Rotjan.

An aspect of deep-sea ecology that Rotjan is studying is the immune systems of corals that can live for thousands of years. She wants to understand how they heal from attacks by coral-eating predators, or corallivores. This could offer new insights into how innate immunity evolved among some of the earliest, multicellular animals on Earth. It could even have applications in medicine, because we share ancient ancestors with corals.

Expeditions such as Rotjan's hold immense potential to inspire the public about the deep. Footage of deep-diving whale sharks and a pair of exquisite glass octopuses sparked enormous responses online. For Rotjan, these glimpses of deep-sea ecosystems are crucial reminders that we share the world with so much hidden life. "What we really need, as stewards of this planet, is to protect our neighbours," she says.



A squat lobster nestles on a golden coral

View inside the Aquarius habitat, the world's only undersea research station

WILL WE EVER BUILD A DEEP-SEA BASE?

Technically speaking, there is nowhere in the abyss that's entirely off limits to humans. A growing roll call of brave and curious people have paid brief visits to the ocean's greatest depths. Earlier this year, Nicole Yamase became the first Pacific Islander, the third woman and the youngest person to descend into the Challenger Deep in the Mariana Trench, the ocean's deepest point at close to 11 kilometres down.

But going down and staying down is a different undertaking. The people who have so far spent the longest time deep underwater are commercial divers who carry out construction work on oil and gas installations. They spend weeks inside pressurised capsules on ships and oil rigs, commuting each day inside a diving bell to their work site 100 metres or more below. Their bodies stay saturated with diving gases the entire time, until they are slowly decompressed at the end of each mission.

Scientists have also adopted saturation diving as a means of spending more time at greater depths. A pioneer of this was French underwater filmmaker, Jacques-Yves Cousteau, who in the 1960s built a starfish-shaped underwater base in the Red Sea called Conshelf II. His grandson, Fabien Cousteau, is now planning a next generation, deep-sea facility called Proteus.

"In order for us to understand something as complex, something as mysterious, something as foreign as the ocean world, one has to spend a lot of time down there," Cousteau said, when we spoke about Proteus on the *Catch Our Drift* podcast.

Dubbed the first International Space Station for the ocean, Proteus will be a larger and more adaptable version of previous underwater habitats including Aquarius in Florida – the only one still in operation and where in 2014 Cousteau spent a record-breaking 31 days living underwater.

Eventually, Cousteau hopes there will be a network of Proteus bases through the ocean, to be used by scientists and filmmakers, as well as astronauts training for the rigours of space. The first base will accommodate a team of 12 aquanauts and is due to be installed in a marine protected area off the island of Curaçao. It will be in around 18 metres of water, so not exactly the abyss, but still proof of concept for groups of people living and working underwater.

> "We want people to be able to dream, to be able to connect with the ocean"

Proteus will even house the world's first underwater greenhouses to grow fresh food for the crew and a broadcast studio to help communicate the wonders of the deep. "We want people to be able to dream, to be able to connect with the ocean," said Cousteau.

4 WILL THE CLIMATE CRISIS CHANGE THE DEEP SEA?

Lanternfish, like this one pictured from below, may soon be targeted by fisheries. But these little fish play a key role in transferring carbon to the deep

YVES BÉHAR/FUSEPROJECT, DAVID SHALE/NATUREPL.COM

Climate change is already reaching down into the deep ocean. A 2020 study confirmed the average global temperature between the surface and 2,000 metres has been rising year on year. The increase may seem small — in 2019, it was 0.075°C above the average between 1981 and 2010 — but due to the volume of water, the heat absorbed is equivalent to the energy of 3.6 billion atomic bombs exploding.

And there are greater changes on the way. By the end of the century, it's predicted temperatures in the twilight and midnight zones, down to 1,000 and 4,000 metres respectively, will rise to 8°C. This will come as a hot shock for deep-sea organisms that are adapted to around 4°C.

Other climate impacts will accompany the rising temperatures. Ocean acidification is expected to hit hardest between 200 and 3,000 metres down, where deep-sea corals will find it increasingly difficult to make their exoskeletons. Warming seawater will lose its ability to hold oxygen. In the northeast Pacific, off Vancouver Island, oxygen levels down to 3,000 metres have already declined by 15 per cent over the last 60 years.

Human impacts are likely to reduce the ability of the deep to buffer against rising carbon concentrations and temperature.

A recent study estimates that trawling disrupts seabed carbon stores and causes emissions similar to the aviation industry. There are also plans to fish the open waters of the twilight zone for lanternfish, thought to be the world's most abundant vertebrates. Each night, huge shoals of the fish migrate from the twilight zone to feed in the shallows, before fleeing back to the deep at dawn, bringing masses of carbon with them. Hunting these fish in large numbers could cut off a critical pathway of carbon into deeper waters.

Plans to begin mining the abyss likewise come with worrying predictions. Mining could disturb seabed carbon stores, potentially on a larger scale than trawling. Contaminated wastewater extracted from the mined slurry could be disposed of by pumping it into the twilight zone, where it would choke gelatinous midwater animals such as jellyfish and siphonophores, all of which are important in the drawdown of carbon into the deep.

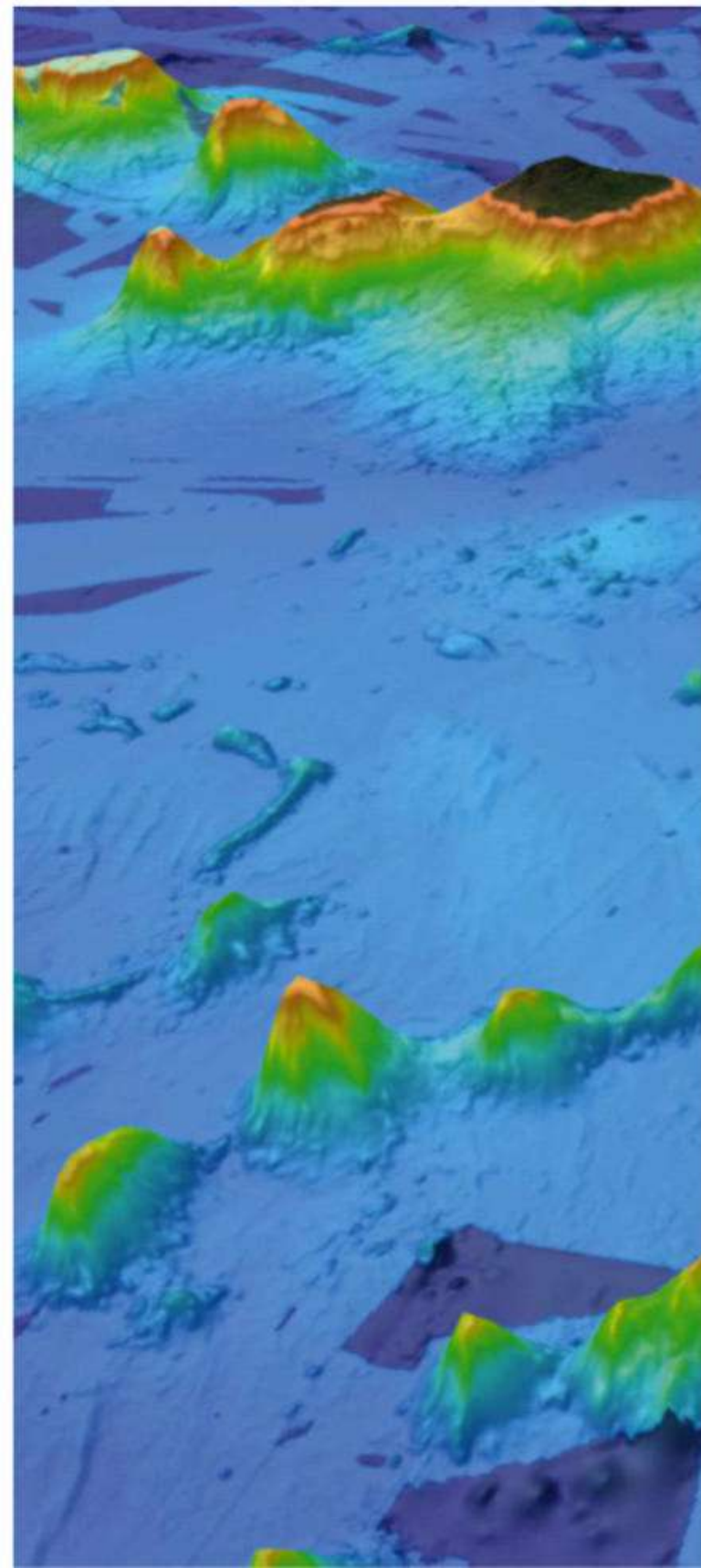
A great unanswered mystery is whether seabed mining would help solve the climate crisis by providing metals to make green technologies like electric car batteries, or make the situation a great deal worse.

5 WHAT DOES THE DEEP SEABED LOOK LIKE?

It's been said many times that we know more about the surface of the Moon than the bottom of the sea. This is true, at least in terms of the maps we have, but it's a fact that's gradually changing.

The entire surface of the Moon has been mapped to a resolution of seven metres. Compare that to the best complete maps of the seabed, which are created using satellites that measure bulges in the sea surface and only show features that are at least five kilometres across. It's worth bearing in mind that the area of the Moon is about 10 times smaller than the Earth's seabed, and with no ocean getting in the way it's a good deal easier to see what's going on up there. Even so, scientists and engineers are finding new, better ways of mapping the bottom of the sea.

The Nippon Foundation-GEBCO Seabed 2030 project aims to map the entire seafloor by the end of the decade through data donated by governments, researchers, industry and private individuals. The plan is to obtain a depth reading for every 800 x 800m pixel of the deep seabed. For areas shallower than 1,500 metres, that goes down to one reading per 100 x 100m pixel.



RIGHT
The *Maxlimer* is an uncrewed vessel that deploys and retrieves an autonomous submersible

BELOW
A state-of-the-art echo sounding device that can map the seafloor

FAR RIGHT
The Seabed 2030 project is building better topographical maps of our seabed. You can explore it further here: **bit.ly/seabed-map**

Better seafloor maps will serve all sorts of purposes. They will help us navigate, they will aid in the laying of telecommunications cables, and they will improve our understanding of how seabed topography influences currents and the mixing of water, allowing us to make better climate change predictions.

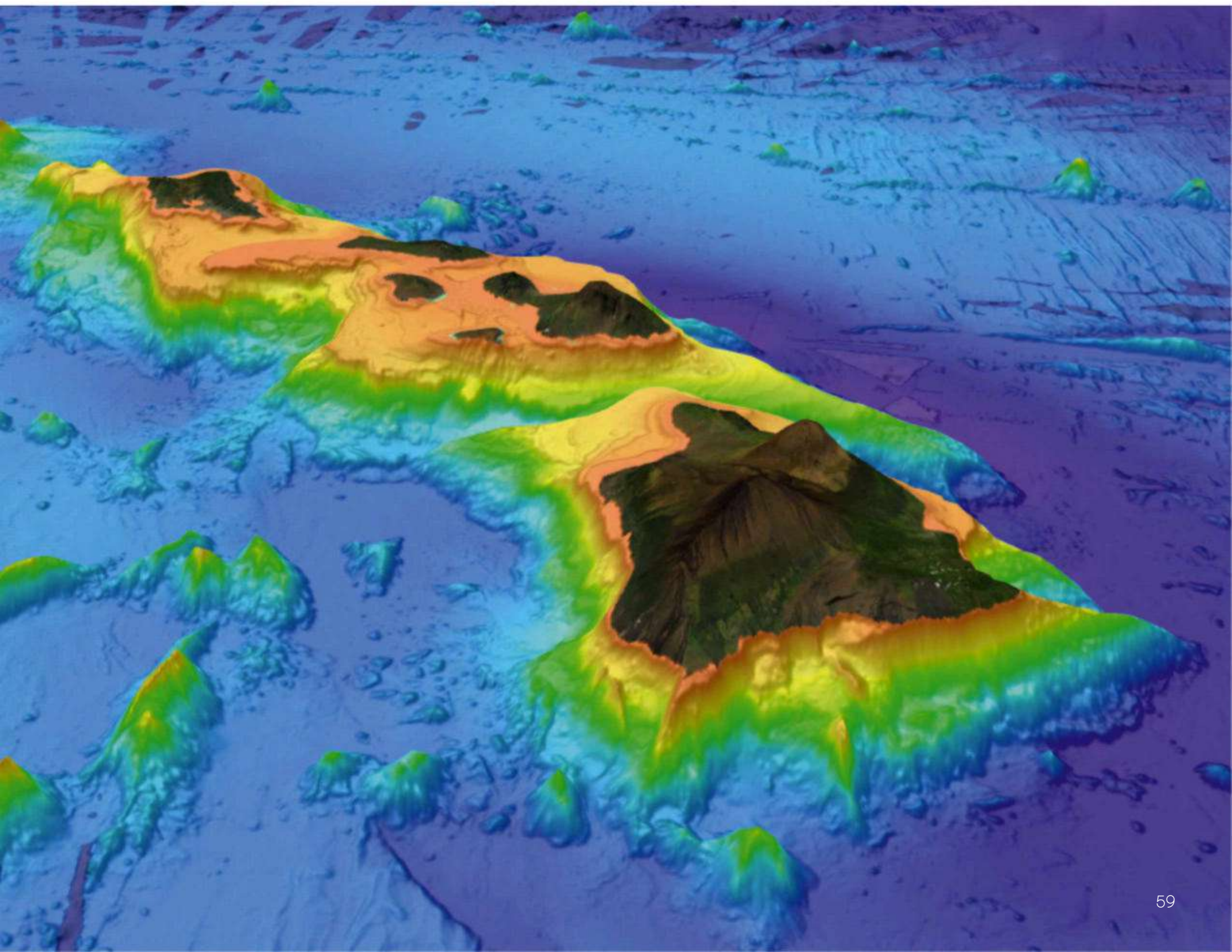
In 2021, Seabed 2030 passed the 20 per cent mark, so there's still a long way to go. A new generation of Uncrewed Surface Vessels (USVs) could help meet the challenge, including a fleet based on the design that won the 2019 ocean-mapping XPRIZE. The Sea-Kit *Maxlimer* deploys and recovers an autonomous submersible that echo sounds the depths. It also recently hit the headlines when it navigated across the North Sea, carrying oysters and beer from Belgium to England – a first for a commercial, robotic ship.

As well as plans for a global map, portions of the abyss are also being charted in greater detail, to make maps of giant underwater mountains. When Rotjan was co-leading the recent expedition to the Pacific on the *RV Falkor*, her team studied 14 seamounts, including 10 that were previously unvisited. They used an array of the ship's onboard sensors, including a multibeam echo sounding system, to interrogate the seabed. As the data flowed in, three-dimensional maps were drawn and the scientists started planning where to dive.

When studies of those seamounts are published, the scientists will have a chance to name them. There's a formal process for naming seamounts and there are rules to stick to. You can't, for instance, name them after a living person. Rotjan and her team have some thoughtful and fun ideas drawn from history and popular culture, but for now they're keeping them under wraps. SF

by DR HELEN SCALES

Helen is a marine biologist, broadcaster and author. Her latest book is The Brilliant Abyss *(£16.99, Bloomsbury Sigma). She co-hosts the* Catch Our Drift *podcast at* ***catchourdrift.org***



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The new series of *Just One Thing* started on 29 August. Listen or download at **bit.ly/BBC-one-thing**

COMMENT

GIVE FLU THE COLD SHOULDER

There is mounting evidence that braving an icy shower in the morning could keep illness at bay and may even help your brain stay sharp. Brrrrrr!

Recently, I made a 10-part Radio 4 podcast called *Just One Thing* where in each 15-minute episode I explored the science behind simple things you can add to your daily routine, like squats, eating more fermented food or going for brisk, early morning walks. It was an instant hit and was immediately recommissioned. You can find the original series on BBC Sounds, where you will also find the latest episodes of the second series.

One of the most popular episodes from the first series explored the risks and benefits of cold water immersion. For this episode I started having cold showers every morning, starting with a brief burst of hot water, followed by 45 seconds or so of an icy cold blast.

It certainly perks you up, but is there anything more to it than that? Well, there was a Dutch study published in 2016 in the journal *PLOS One* where they recruited 3,018 people online and then randomly allocated them to having a cold shower every morning for a month, or to a control group who continued as normal. Those having the cold shower were further divided into those asked to do it for 30 seconds, 60 seconds or 90 seconds.

"People having cold showers were 30 per cent less likely to take time off for sickness"

Over the following winter there was an outbreak of flu and it turned out that those people having cold showers were 30 per cent less likely to take time off for sickness than those in a control group, though it didn't matter whether you were in the 30-second group or either of the longer groups.

As for improving mental health, there haven't been any shower-related studies I could find, and even the cold water swimming claims rely more on anecdote and case studies than strict randomised controlled trials. That said, researchers from Cambridge University appear to have found a mechanism. A few years ago they identified a 'cold-shock' protein called RBM3, which in mice rises in response to sudden cooling and seems to be important for creating new connections between neurons in the brain. More recently, they found higher levels of RBM3 in the blood of regular cold water swimmers.

If you like the idea of cold water swimming during the coming months, do be cautious and go with a friend or join a club. A few years ago I was out swimming with my wife, Clare, when suddenly everything went black. A few hours later, I came to in hospital. Clare said I had swum to the shore and then looked around blankly, with no idea where I was. It turns out I'd experienced something called 'transient global amnesia', brought on by the cold water. Thankfully it soon passed and the consultant said it was unlikely I would experience it again. Nonetheless, come the end of September I will stop outdoor swimming, but continue with the cold showers. SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor.* His latest book is *COVID-19: Everything You Need To Know About Coronavirus And The Race For The Vaccine* (£6.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JOE WALDRON

COMMENT

A NICE CUP OF TEA

Worker shortages and the pandemic have left our supermarket shelves emptier than usual. What will it mean if supplies of our favourite drink start to dwindle?

In 1942, in the midst of WWII, the British government procured what you might expect: bullets, artillery shells, bombs. These were the ingredients for battle, purchased to protect the population from physical harm. But they were also thinking about hearts and minds – the other battle on the home front – and what they needed to do to ensure that the country had the resilience to keep calm and carry on. So to tackle that psychological battle, they bought all the tea in the world. And by golly, we won.

It makes sense from an emotional level. Tea is a crucial symbol for the nation. It's the great caffeinator, the morale booster, more powerful than ammunition (so said Winston Churchill). And yet, it is a precarious property. Not nearly enough tea is grown in-country to warrant our obsession, yet even coffee drinkers rely upon it being on the shelves to prove to ourselves that everything's going to be just fine. It isn't only symbolic because it's been brought in to get us through wars, but because it is the clearest evidence that Britain is connected with the rest of the world. After all, we need to have good relationships with everyone else to get enough of the stuff into our teapots.

Ensuring tea was on our shelves during the darkest days of WWII meant making diplomatic decisions, and not just about wartime budgets – although one estimate has tea as the second highest spend during 1942. It meant keeping the workers in Assam safe, the US on side to deliver the goods using their ships, and the Chinese in silver (and, unfortunately, opium).

"Even coffee drinkers rely upon tea being on the shelves to prove that everything is fine"

The result was that Britons, wherever they were, got their cups of tea and everyone felt things were going to be okay.

Fast forward to now, a different diplomatic era, and images on social media of high street supermarket chains' empty tea shelves are spreading symbolic messages to a country battered by multiple theatres of 'war'. There are likely many practical and political factors contributing to this, but for me the most important part is what impact it has on the British psyche. The issue is clearly at the forefront of the supermarkets' minds too; in many cases they've hidden the lack of consumables with cutouts of boxes, or jolly slogans that try to brush off the 'end is nigh' feeling that might cause riots on the streets and in the toilet paper aisle. Which, given the overall tension, we are likely to do.

But the problem is that almost 80 years since the government trawled the globe for tea leaves, it is a fragile litmus test for the country's wellbeing. Having tea in the pot relies on our relationships with other countries. It requires supply chains that work. It leans too heavily on imaginings of Empire glory, and trade negotiations that have been usurped by beliefs of self-sufficiency. The symbolism behind the resilience of a nice cuppa is now that the British identity requires a transformation, and (to borrow from the French) tout suite.

What could replace tea as the national foodstuff? Is there something homegrown and sustainable that the UK could align itself with? There's only one thing to do to solve this puzzle: sit down with a nice cuppa and a biscuit to worry this out. SF

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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ONLY IN YOUR WILDEST DREAMS

WORDS: DR CHRISTIAN JARRETT

Even today, scientists don't know why we dream. But now psychologists have found a way to communicate with lucid dreamers – people who can take control of their dreams – in the hope that they might help us explore what goes on with our brains at night

Billionaires are jetting themselves into space and quantum computing lies around the corner. Yet one of the most familiar and everyday aspects of human nature remains frustratingly tricky for scientists to study – dreaming.

Theories abound, but the truth is we don't really know much about why or how we dream. A major hurdle for scientists has been the fact that when people are dreaming, they're largely closed off from the world, at least that's been the assumption for a long while. So researchers have resorted to asking people, upon awakening, what their mind was doing while they were sleeping, but that's a sketchy and unreliable approach.

"Memories of dreams can be missing some parts of dreams and can be distorted and incorrect, so if that's all we have to go on, then building a solid science of dreaming will be difficult," says Dr Ken Paller, a psychologist and dream researcher at Northwestern University.

What would change the whole dream research landscape would be if there were some way to communicate and interact with someone while they were dreaming. It sounds far-fetched, like something out of the Christopher Nolan movie *Inception*, but in a significant breakthrough, that's exactly what an international team of researchers, led by Paller and Karen Konkoly also at Northwestern University, managed to achieve. The work, which was published in the journal *Current Biology* earlier this year, "opens up the opportunities for scientific explorations of dreaming considerably," says Paller. "We now have more ways to learn about dreaming."

Theirs is one of several new projects that have begun to exploit the research opportunities afforded by 'lucid dreaming' – a relatively rare state in which the dreamer, during rapid eye movement (REM) sleep, becomes consciously aware that they are dreaming. This is a new frontier of research, but lucid dreams have been known about for millennia. Aristotle described the state like this: "...often when one is asleep, there is something in consciousness which declares that what then presents itself is but a dream".

Not only does this wave of new work involving lucid dreams open up exciting opportunities to research the nature and function of dreaming, but it also raises intriguing practical possibilities for clinical interventions and self-development, including boosting learning and creativity.

CHOOSE YOUR DREAM

If you've ever been in a dream and known you were dreaming, then you've experienced the lucid dreaming state. It's estimated that about half of us fall in this category, with around 20 per cent ➲

ILLUSTRATION: SAM FALCONER

of us experiencing the phenomenon on a monthly basis and 1 per cent having several such experiences each week. Sometimes, people in a lucid state can even begin to deliberately choose what happens in their dream, as if they were a director of their own movie. This degree of conscious control is important for scientists because it raises the possibility that the dreamer might be able to choose to communicate with the outside world.

In terms of what's happening in the brain during lucid dreaming, research is at a relatively early stage. There have been several studies that measured people's brainwaves via an EEG during lucid dreaming, but it has only been captured in a modern high-resolution brain scanner a handful of times. "In short, we still don't know what the localised brain activity changes are associated with lucid dreaming," says Dr Benjamin Baird at the Wisconsin Institute for Sleep and Consciousness, University of Wisconsin-Madison, who has studied the neural correlates of lucid dreaming. "There is some preliminary neuroimaging data which suggests a role of the frontoparietal network [a network of connected regions spanning the front and rear of the brain that's involved in attention and problem solving]," he adds, though he notes more research is needed to confirm this.

One thing Baird says does seem clear is that lucid dreaming seems to occur during periods of more intense brain activation during REM sleep.

"REM sleep has peaks and valleys of activity when the brain is more or less activated as it goes along," he explains. "We become lucid at the mountain peaks of brain activation, when we are in the mental set of trying to recognise that we are dreaming – or sometimes by chance if something triggers us to consider whether we are dreaming."

ENTER DREAMWORLD

If you've never had a lucid dream, you might be wondering what it feels like. One person who is highly familiar with them is Dave Green, the English comedian turned lucid-dream artist, who first started having lucid dreams as a child. "Having a lucid dream is like being embodied in your imagination," he says. "You are navigating an environment that is entirely created by your mind, yet it looks and feels like waking life."

"YOU ARE NAVIGATING AN ENVIRONMENT CREATED BY YOUR MIND, YET IT LOOKS AND FEELS LIKE WAKING LIFE"

Unable to perform stand-up comedy during the pandemic, he rediscovered lucid dreaming and started using the experience to conjure artworks that he then creates upon waking. "Besides creating artworks, my favourite thing to do in a lucid dream is flying. It is never anything less than ecstatic," he says. (If you are keen to experience this for yourself, the good news is that lucid dreaming is to an extent a trainable skill – see the opposite page for some basic techniques.)

For their breakthrough lucid dreaming study, Konkoly and Paller, along with their colleagues at other laboratories in France, Germany and the Netherlands, exploited the residual conscious awareness enjoyed by lucid dreamers. To do this, they recruited several experienced lucid dreamers, as well as some lucid dreaming newbies, who they trained to experience lucid dreams.

Next, they used a procedure developed by fellow dream scientist Dr Michelle Carr and her colleagues, in which beeps and flashing lights are repeatedly paired during wakefulness with an instruction to become lucid – that is to become mindful of one's thoughts and sensations, and to consider whether they reflect being awake or in a dream. Konkoly and Paller's team then used these same sounds or lights while their participants were sleeping (as confirmed objectively by a measure

DAVE GREEN ILLUSTRATIONS: SAM FALCONER

Comedian Dave Green creates artworks while lucid dreaming, then draws them upon waking

of their brainwaves) to prompt them to become lucid while dreaming. Crucially, if the study participants entered a lucid dream state, they were trained to indicate this by making sweeping horizontal movements with their eyes.

At this point, the researchers had used dreamers' eye movements to establish communication from within their dreams to the outside world. That's been done many times before, notably by the American psychophysiologist Dr Stephen LaBerge in the early 1980s as a way to objectively verify the lucid dreaming phenomenon – that is, that lucid dreamers really are aware and able to respond. But Konkoly and Paller and their international collaborators then went further, to create a situation of truly "interactive dreaming" as they called it. After participants indicated they were in a lucid dream, the scientists gave them basic maths questions, such as 'eight minus six', which the participants answered successfully using eye movements, according to a code agreed earlier (for instance, in this case, the answer 'two' was communicated by a left-right, left-right eye movement).

HOW TO HAVE MORE LUCID DREAMS

There are three main techniques that dream researchers recommend for increasing your odds of experiencing a lucid dream, which can either be used on their own or in combination

The first technique is 'reality testing' which involves making a regular habit during wakefulness of testing whether you are asleep or awake. For instance, several times a day you might check whether you can press the fingers of one hand through the palm of your opposite hand (a feat that is usually possible in dreamland, but obviously not while awake). This might sound odd, but the idea is that if you get into the habit of doing this while you're awake, you'll be more likely to try doing it while you're dreaming, and if you ever do, you'll realise that you're dreaming and you'll become lucid.

Another technique is called 'Wake Back To Bed' (WBTB) and involves setting an alarm for approximately two to three hours before you usually wake up. Upon waking, you then allow yourself to drift right off back to sleep, but with the renewed intention to lucid dream. The rationale here is that lucid dreaming occurs during REM sleep (the stage of sleep when narrative dreaming is most common) and so you're waking yourself up at just the right time of night when you're likely to be in the midst of REM sleep, and then diving right back into it with the active plan to lucid dream.

The final technique is called Mnemonic Induction of Lucid Dreams (or MILD for short), which involves repeating a mantra to yourself several times before you go to sleep, along the lines of "the next time I'm dreaming, I will remember I'm dreaming". You can either try it when you first go to sleep at night , or you can combine it with WBTB in the early hours of the morning. Dave Green, the comedian turned lucid-dreaming artist, recommends the MILD technique: "I just repeat over and over again 'Tonight I will have a lucid dream and create a drawing'," he says.

By now the researchers had broken exciting new ground, successfully achieving two-way communication with participants while they were dreaming. They had succeeded at their goal, which as they put it in their paper, was "akin to finding a way to talk with an astronaut who is on another world, but in this case the world is entirely fabricated on the basis of memories stored in the brain."

"[THE RESEARCH IS] AKIN TO FINDING A WAY TO TALK WITH AN ASTRONAUT WHO IS ON ANOTHER WORLD"

SLEEP TALKING

The study by Konkoly, Paller and their colleagues was focused on establishing a two-way communication between a dreamer and the outside world. It was a proof-of-concept study that promises to pave the way for many new and exciting projects, both to uncover more about the nature of the dreaming brain and for practical interventions to enhance learning and creativity, for instance. However, even without the capability of two-way communication, other researchers have already tested the potential of lucid dreaming in various ways.

For example, there is such as thing as lucid dreaming therapy, which involves teaching lucid dreaming techniques to sufferers of nightmares, so that they can choose to wake up from a nightmare or even change the narrative so that its content is less distressing.

Other researchers have explored the possibility that lucid dreaming could be used to practise motor skills. Dr Daniel Erlacher at the University of Heidelberg and Dr Michael Schredl at the Central Institute of Mental Health in Mannheim, assigned a group of lucid dreamers to repeatedly toss a coin into a cup in their dreams. Compared with their baseline real-life performance, the participants' accuracy the next day was improved by a greater amount than a control group who didn't do any further coin-tossing practice in real life or dreamland.

It might also be possible to exploit lucid dreams to aid creative problem solving. For instance, Dr Tadas Stumbrys and Dr Michael Daniels at Liverpool John Moores University found that lucid dreamers were able to call on the help of dream characters to help them come up with more creative metaphors.

ILLUSTRATIONS: SAM FALCONER

Crucially, the two-way interaction between dreamer and outside world established by Konkoly and Paller and others could build upon and expand these various ways to exploit the lucid dreaming state. For instance, their model of interactive dreaming suggests that sensory cues could be associated with desired dream content in advance and then played during the lucid dream state, making it more likely that the lucid dream will involve features that could help aid creativity or contribute to learning.

ADVERTS WHILE YOU SLEEP

That said, the path ahead is not likely to be all plain sailing. "[The technique for communicating with lucid dreamers] does not work every time we try," says Paller. "We are in the process of improving our methods, so I don't know how reliable they could be eventually." Indeed, Paller cautions against getting too carried away: "I have an open mind about the potential for this method to be useful in the future," he says.

Another elephant in the room (probably a flying pink one, if you're dreaming)is the ethical issues raised by this entire line of work. If researchers can reach into our dreams and affect what we dream about, then that presents the possibility that other people can too, such as advertisers who might reach us in our sleep via smart speakers or other devices. Indeed, that's already begun happening: early in 2021, American beer company Coors experimented with deliberately inducing dreams of their product among volunteers.

These developments recently prompted a large group of dream scientists, led by Dr Robert Stickgold at Harvard Medical School and Dr Antonio Zadra at Université de Montréal, to write an op-ed warning of the ethical dangers of advertisers exploiting the advances in their field. "Brain science helped design several addictive technologies, from cell phones to social media, that now shape much of our waking lives; we do not want to see the same happen to our sleep," they wrote.

Paller and Konkoly were actually among the co-signatories of the letter, and they too are mindful of the important ethical implications of their work. "Messages delivered during sleep to an unwilling individual could be regarded as a form of inappropriate advertising and made illegal," says Paller.

As Zadra elaborates, "While the technologies themselves are neutral and hold promise in fostering creativity and treating psychological disorders, their use to alter and motivate purchasing behaviour through dream hacking is worrisome."

Just as science has taken us to uncharted territories in space and on Earth, raising new ethical questions along the way, the same is now true for a new frontier as researchers accelerate their exploration of our sleeping minds. SF

by **DR CHRISTIAN JARRETT**
(@Psych_Writer)
Christian is a neuroscientist and deputy editor of online magazine Psyche. *His latest book is* Be Who You Want: Unlocking The Science Of Personality Change *(£14.99, Robinson).*

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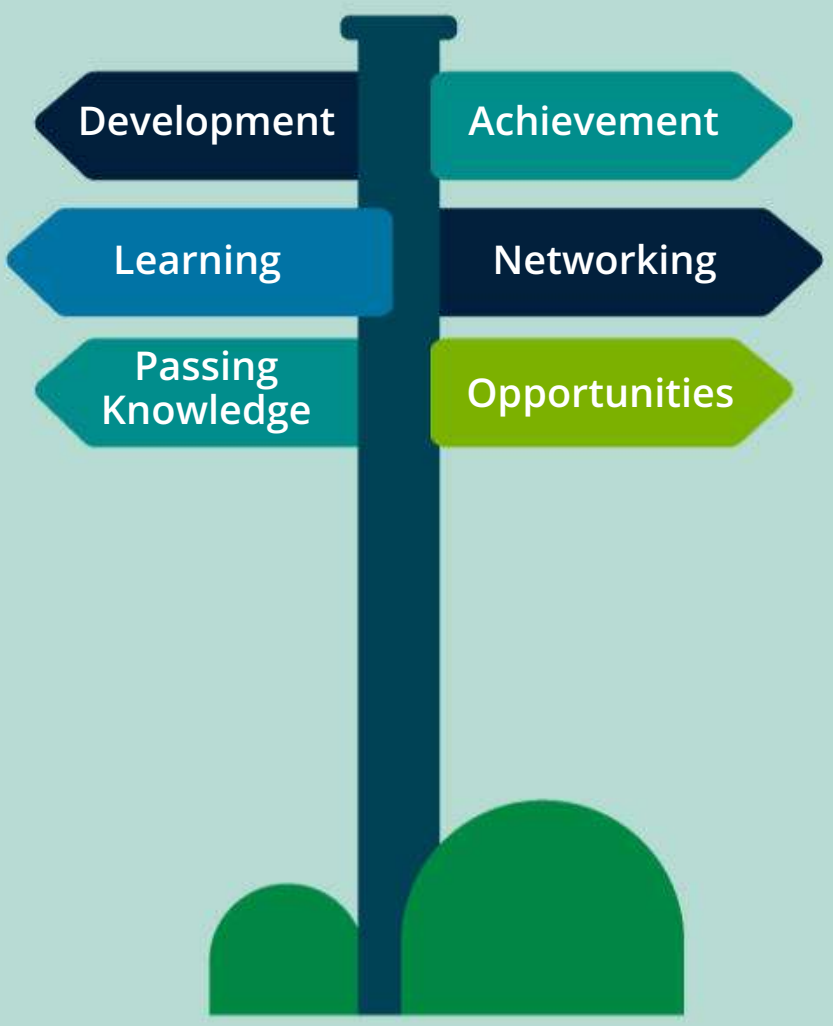

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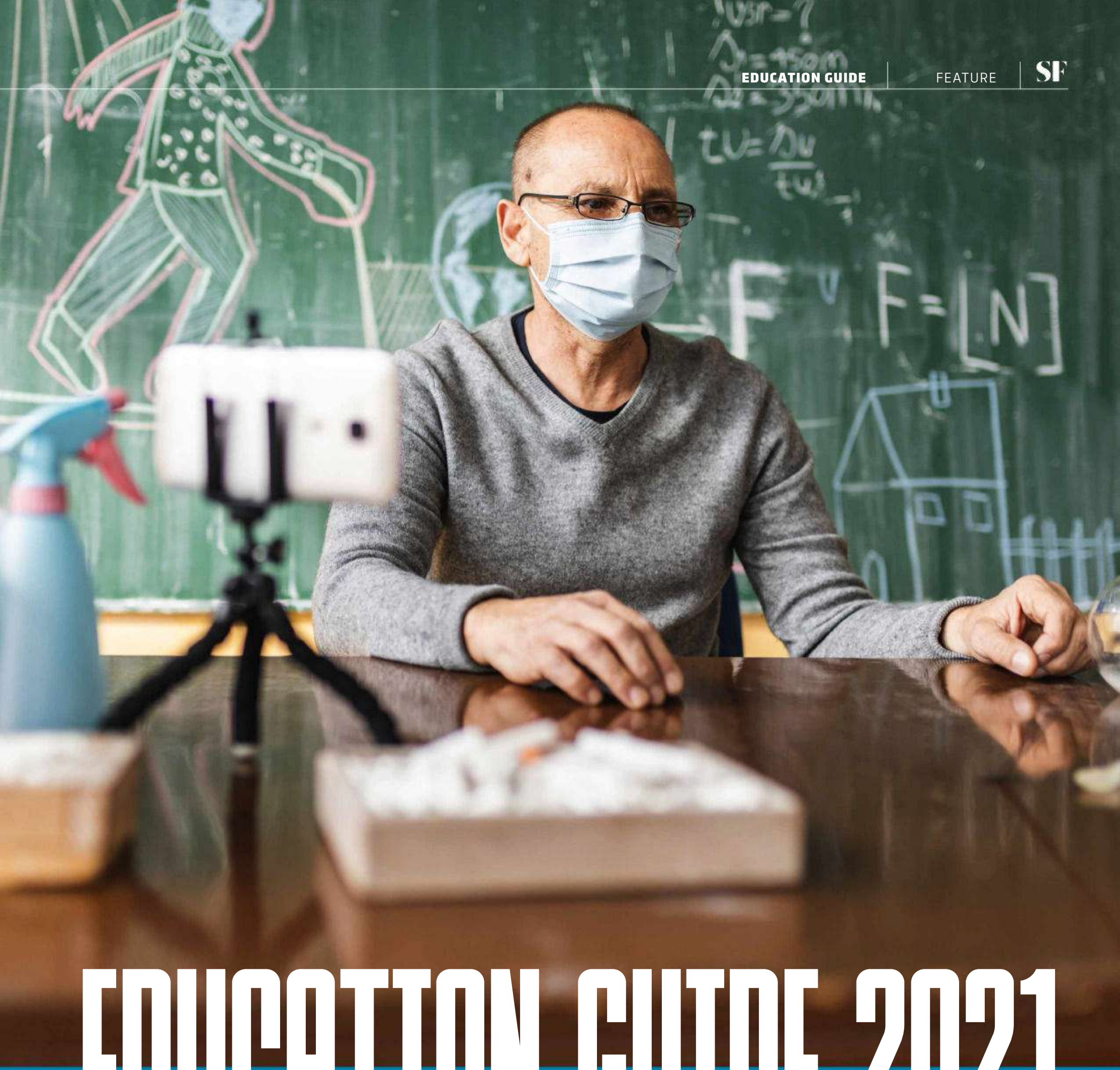

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CAN YOU CHANGE CAREERS IN YOUR 30s?

The events of the last year or so have spurred many to rethink their careers. An occupational psychologist offers some advice on how to make the leap

WORDS: **SARAH DALE**

A recent poll by Aviva suggested that 60 per cent of UK workers plan to make changes to their career. Some want to find work that helps others, or that creates an income from a hobby, or allows for more flexible working. Those in the 25 to 34 age group are most likely to want to retrain to pursue a completely different career path from their current one. These numbers have increased since the pandemic started.

There was already turbulence in the workplace, with many people and organisations feeling the impact of new technology, demographic changes, political decisions and climate change. The pandemic has brought new disruption, creating further uncertainty as well as the opportunity to review career direction.

Prof Herminia Ibarra, from the London Business School, asserts that the change many people seek is a fundamental shift in working identity and that this requires a 'test-and-learn' approach rather than a 'plan-and-implement' one. Her research shows that, on average, career transition takes three years. It is more successful when people gain new experiences to base their decisions on, rather than attempting to think it all through in theory before acting. This takes courage and needs support to go through the challenging but rewarding 'liminal' period between a past that no longer fits and an uncertain future. It can be both exciting and frightening. It's not easy.

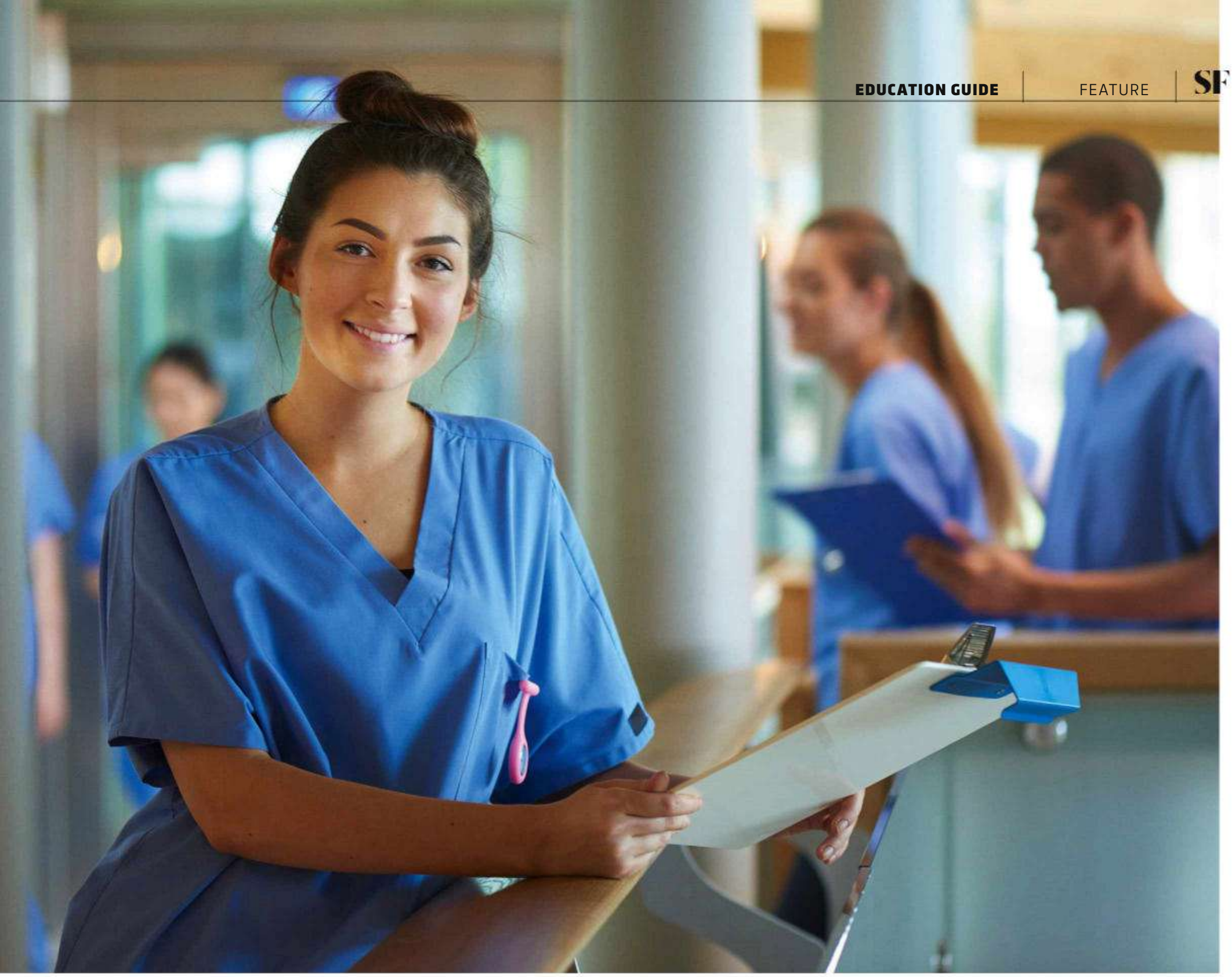
MAKE THE CHANGE

Difficult childbirths brought Sarah (chartered accountant to registered nurse at 36) into close contact with health professionals. She learned what their jobs entailed and was inspired to make a change that led to work that impacted directly on people's lives. Over the ensuing 20 years, she has progressed to teaching student nurses and leading research aimed at improving the healthcare of people with dementia.

Jon (architect to children's author at age 30) had been writing for five years alongside his first career. When he was made redundant, he and his family gave him a year to focus on writing full-time as a serious experiment – which worked. Now in his 50s, he has made a living from it ever since.

In my experience, as an occupational psychologist supporting people undergoing such change, motivation is the key element

ABOVE People no longer expect to have a job for life, so don't stick with a career if it's not working for you any more



ALAMY, GETTY IMAGES

that enables success. People find ways of doing things that they *really* want to do, despite the fear and perceived barriers. The 'doing' is important. Career change can falter when people get stuck in their imaginations, at their desk, trying to create a failsafe strategy before gaining any real-world experience.

Before making the leap, there are experiments you can do, like evening courses, voluntary work, working holidays and shadowing. Think about who you need help from, and what you are prepared to do, in order to make the change. Consider what you can live without, at least on a temporary basis. What is the pay-off, emotionally, for you and your family?

Andy (chartered engineer to plumber and gas fitter at age 35) had a climbing accident and lost the sight in one eye. "I came to realise that I was not invincible," he says. "I started thinking about how I was going to spend my remaining days on Earth. Working in an office wasn't for me and probably never was. Time to go." The pandemic has given many people similar pause for thought. Andy says his retraining was a 'leap of faith' that was fully supported by his wife. He has no regrets.

Jill (marketing executive to primary school teacher at age 39) changed direction after having children. Once she'd taken the plunge, her determination and motivation were at all-time highs, allowing her to prioritise effectively in whatever hours were available. In addition, her corporate experience gave her valuable project management and communication skills.

I have learnt from working with many people that nothing is wasted in terms of prior experience. It all feeds into new careers, often in surprising ways. Age was not seen as a barrier for anyone I have asked or worked with. Usually, their experience was more of a benefit than a drawback.

Career change is possible. It takes courage, support and experimentation, and it rarely happens overnight. There will be setbacks as well as progress. But the pandemic has highlighted that life is precious and finite, and that there is plenty that needs doing in our unsettled world. Now could be the time. **SF**

by **SARAH DALE** *(@creatingfocus)*
Sarah is an occupational psychologist and writer, who runs her own practice in Nottingham.

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WORDS: **HAYLEY BENNETT**

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futurelearn.com/courses/the-science-of-medicines

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University of Exeter

futurelearn.com/courses/climate-change-the-solutions

This popular FutureLearn class covers sustainable energy and agriculture, carbon sinks and geo-engineering, it's led by scientists including Tim Lenton, the University of Exeter's Chair in Climate Change/Earth System Science. You get 12 hours of study for free, or for £42 if you want the certificate.

AI for Everyone: Master the Basics

edX / IBM

edx.org/course/artificial-intelligence-for-everyone

This primer covers machine learning, deep learning and neural networks, as well as addressing AI ethics and impacts on society. It takes about four weeks to complete at a rate of one to two hours per week. Enrol for free, or pay £72 to take graded assignments and exams and get a shareable certificate at the end. More than 87,000 students have already registered.

The Complete Self-Driving Car Course

Udemy

udemy.com/course/applied-deep-learningtm-the-complete-self-driving-car-course/

In this £50 Udemy course, you'll simulate a fully functional self-driving car and train it to recognise 43 different road signs. You don't need to know programming language, as you'll get a crash course in Python as part of the deal. The lectures are bite-sized at just a few minutes each, but there are 171 of them, totalling 18 hours of learning. Over 18,000 students have taken this class with Canadian software developer Rayan Slim.

Understanding the Body

University of Aberdeen

futurelearn.com/programs/understanding-the-body

Earn credits towards higher level qualifications with this 11-week biology programme taught by lecturers from the University of Aberdeen. It features courses on DNA, organs and tissues, and bodily systems, as well as an optional assessment to gain 10 credits towards a Scottish Vocational Qualification. It's £156 for the course, plus £344 for the assessment.

Fibonacci Numbers and the Golden Ratio

The Hong Kong University of Science and Technology

coursera.org/learn/fibonacci

You can polish off this tempting 10-hour maths course all in one go. Focusing on the Fibonacci sequence (1, 2, 3, 5, 8, 13, 21 etc), it explains why the numbers are related to the so-called 'golden ratio' and how this ratio pops up in in nature, such as the arrangements of leaves on certain plants and the pattern of seeds in a sunflower head. Comes with 10 quizzes and costs nothing to enrol.

by HAYLEY BENNETT *(@gingerbreadlady)*
Hayley is a freelance science writer and editor.

FIVE TIPS TO OPTIMISE ONLINE LEARNING DURING COVID-19

Since the outbreak of the COVID-19 pandemic, in-class learning has shifted to online modes at speed and scale. Here are five ways to optimise the remote learning experience

WORDS: **DR ANDREW J MARTIN**

1. Make instruction explicit

In an online learning environment, there is vast potential for students to lose track of the lesson, go off-task, become distracted, get confused and lose interest. It is important for online instruction to be as well-organised, linear and explicit as possible, especially when students are learning new or challenging content.

'Load reduction instruction' is one approach to help learners keep up with the online lesson. It involves: (1) reducing the difficulty of initial instruction, (2) providing support and scaffolding as students master content, (3) ensuring students practise what they are learning, (4) providing appropriate feedback on assignments and offering improvement-oriented guidance, and (5) providing an opportunity for self-directed learning activities when (and only when) students demonstrate they have mastered the basics.

2. Ensure content is of high quality

Online learning content needs to be optimally pitched to students' existing knowledge and skill. It is vital that the content is not too difficult too soon. When teaching new material, it is best delivered in manageable chunks, so the student is not overwhelmed or confused.

It is worth students remembering that textbooks are written by experts, reviewed by experts, and typically well-targeted to the syllabus. Before grabbing online material, make sure a well-regarded textbook does not do a better job.

3. Stay motivated

Motivation is a cornerstone of online learning. Anecdotally, I have noticed COVID-19 has impacted some parts of motivation more than others. During online learning, students can lose interest, procrastinate and get distracted. Goal-setting can be helpful for planning and staying on track. Our research has demonstrated the benefits of setting a specific self-improvement goal and clearly mapping out the steps involved in achieving this.

'Valuing' is another area of motivation impacted by COVID-19. Valuing refers to the perception that something is useful and connected to one's future life. COVID-19 has meant many exams are cancelled, graduations are called off, courses are modified, and some jobs have been wiped out. What is the value of school if students do not see it linked to future outcomes? One suggestion is to inspire other reasons for valuing learning – such as through interesting content, injecting more enjoyment and fun in lessons, and focusing on other parts of students' lives where learning can be relevant and useful.

A sense of academic helplessness and anxiety have also become salient during this period. COVID-19 has brought huge uncertainty and unpredictability to young people's lives. It is important for students to focus on three things that *are* in their control: effort (how hard they try), strategy (the way they try), and attitude (what they think of themselves and the the schoolwork).

4. Build good teacher-student relationships

Good teacher-student relationships are motivating and a critical support base in the face of academic challenge and setback. In an online group environment it is not always easy to cultivate positive interpersonal relationships, but research has identified three particular opportunities available to teachers: (1) provide emotional support and encouragement, (2) provide content and activities that are well-matched to students' interests, and (3) teach in ways that help students keep up with the lesson. This is referred to as 'connective instruction ' and educators who get these three things right are well connected to their students. It can also be helpful for students to let their teachers know when they find the lesson interesting, and also when they feel lost or do not understand what they have been asked to do. The more teachers know all this, the more they can tailor the online lesson to their students' needs.

5. Foster good mental health

COVID-19 and lockdowns have left many students struggling with mental health and presented major challenges for students with additional educational needs, such as those with dyslexia or ADHD. During periods of online learning, all students must be clearly informed of who to contact inside or outside the school if they are struggling emotionally. Educators will need to maintain closer contact with some students in particular to ensure they are not left behind academically.

COVID-19 aside, schools have been shifting increasingly to online learning for over a decade now – and will continue to do so after the pandemic. Getting these things right is thus an investment in students' online learning now and into the future. SF

by **DR ANDREW MARTIN**

Andrew is a professor of educational psychology in the School of Education at the University of New South Wales, Australia. His research is available at ***researchgate.net/profile/Andrew-Martin-22***

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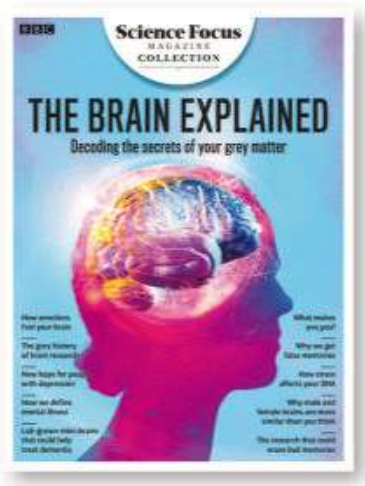

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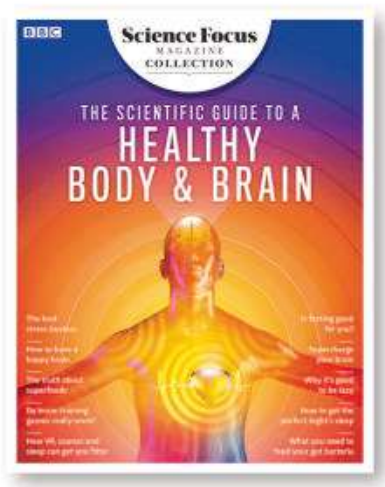

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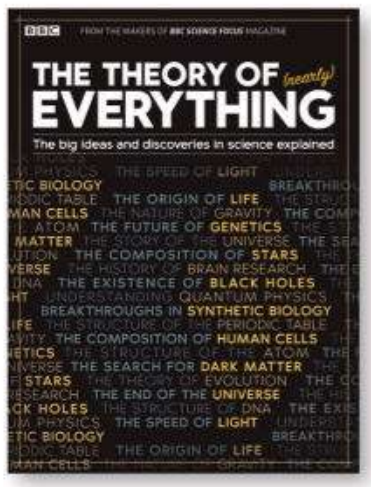

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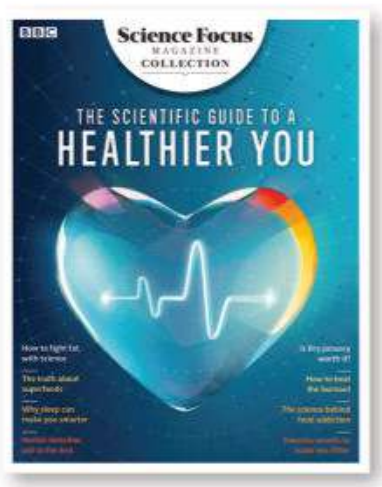

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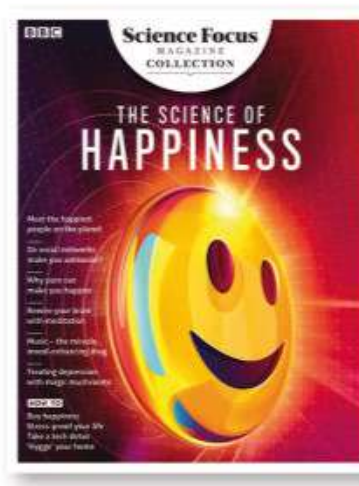

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Q&A

YOUR QUESTIONS ANSWERED

... IS IT POSSIBLE TO MAKE A SHIP OUT OF ICE?
... WERE THE DINOSAURS COLD-BLOODED?
... WHY ARE SEEDS SUCH DIFFERENT SIZES?
... WHY DO I KEEP HAVING RANDOM VIOLENT THOUGHTS IN PUBLIC?
... WHY DO FLAMINGOS STAND ON ONE LEG?
... WHAT'S THE CARBON FOOTPRINT OF STREAMING TV?
... WHY IS FLASH PHOTOGRAPHY BANNED FROM MOST MUSEUMS?
... HOW CAN I SEE THE CYGNUS CONSTELLATION?
... WHY CAN OLD DREAMS FEEL LIKE REAL MEMORIES?

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ILLUSTRATION: DANIEL BRIGHT

DURU GÜNEL AND KEREM GÜNEL, TURKEY

CAN A CORPSE FILLED WITH TRAPPED GAS EXPLODE WHEN CREMATED?

Although many of us would rather not think too much about what happens to our bodies after we die, if you've ever come across one of the rare local media reports of an 'exploding corpse', you probably came away with more questions than answers.

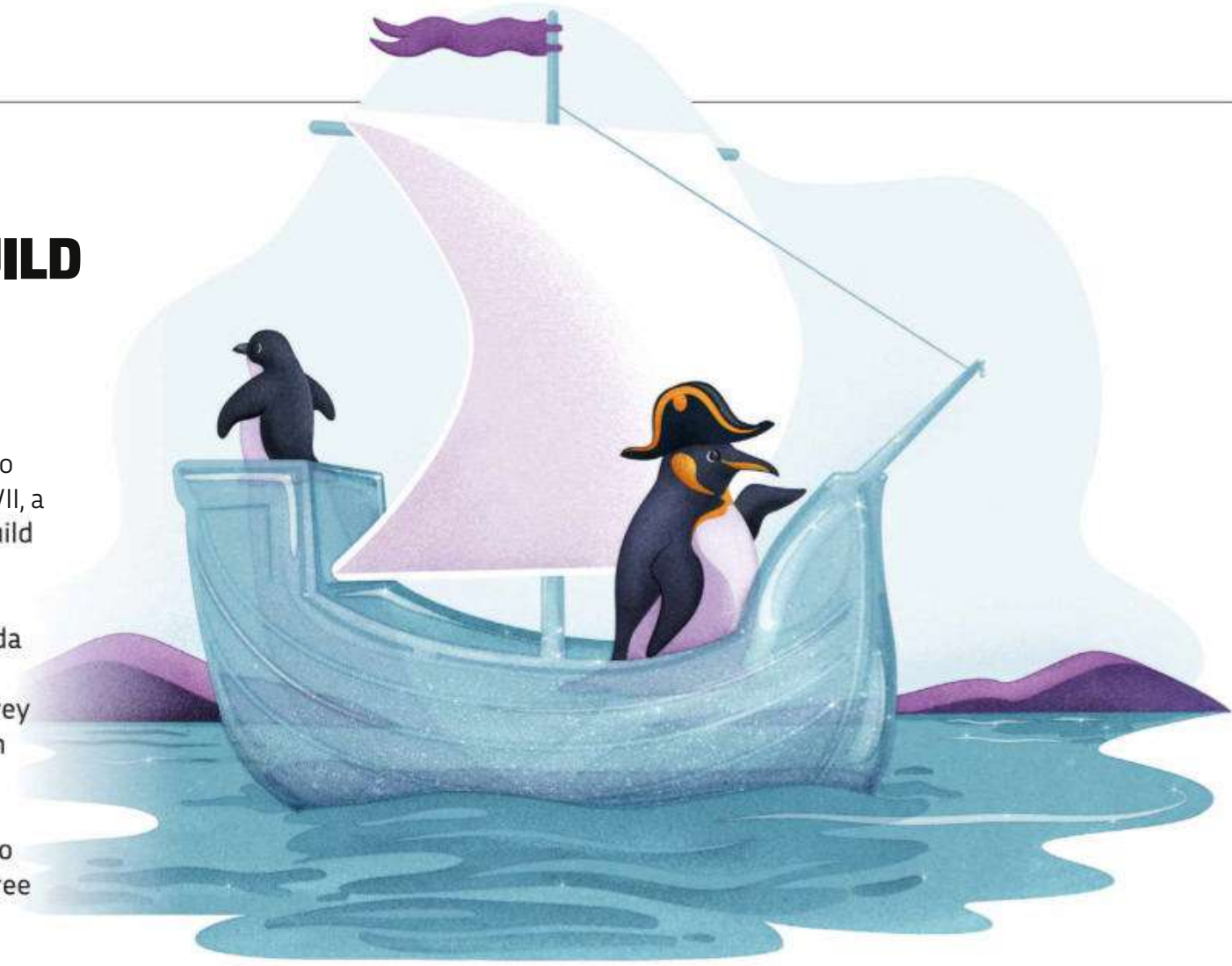
The decomposition process begins just minutes after death – cells become deprived of oxygen and acids, and enzymes start to break them down. Body temperature drops and rigor mortis (the stiffening of oxygen-deprived muscles) starts to set in. Microbes that lived on and in the body during life, no longer kept in line by the immune system, start to digest the decomposing cells. The body then starts to putrefy; soft tissues break down into a liquid and microbes ferment the body's sugars, releasing gases like methane, hydrogen sulphide and ammonia in the process. These gases can build up inside a decomposing corpse and sometimes, if the pressure becomes too high, they can rupture the stomach.

So, an exploding corpse isn't impossible, but it's unlikely to happen during cremation because the body wouldn't be allowed to reach the putrefaction stage; refrigeration or embalming can be used to slow decomposition until cremation. However, above-ground mausoleum caskets that are sealed completely can burst because of the pressure built up from trapped gases. For those intent on a mausoleum burial, an unsealed casket – which can 'burp' to release gases produced during the decomposition process – can avoid this risk.

The gases from putrefaction may not cause a corpse to explode during cremation, but an unexpected pacemaker could. In 1976, the mercury zinc batteries of a pacemaker exploded inside a crematorium in Solihull, breaking the brick lining of the cremation chamber and leading to new regulations on the removal of pacemakers, as well as other medical implants, prior to cremation. ***CA***

HELEN ASQUITH, GREAT YARMOUTH

IS IT POSSIBLE TO BUILD A SHIP OUT OF ICE?



It is possible to build a ship out of ice but warming seas make it a bad idea. There is no escaping the fact that ice melts. During WWII, a British project called Habakkuk aimed to build an aircraft carrier made of ice, partly to overcome steel and aluminium shortages.

The team building the prototype in Canada strengthened ice by adding wood pulp to create pykrete, named after inventor Geoffrey Pyke. But they soon found that it needed an expensive refrigeration system, which required vast amounts of steel. The project was abandoned but pykrete is used today to create ice domes and ice roads. It can be three times stronger than pure ice. ***ED***

NATURE'S WEIRDEST CREATURES...

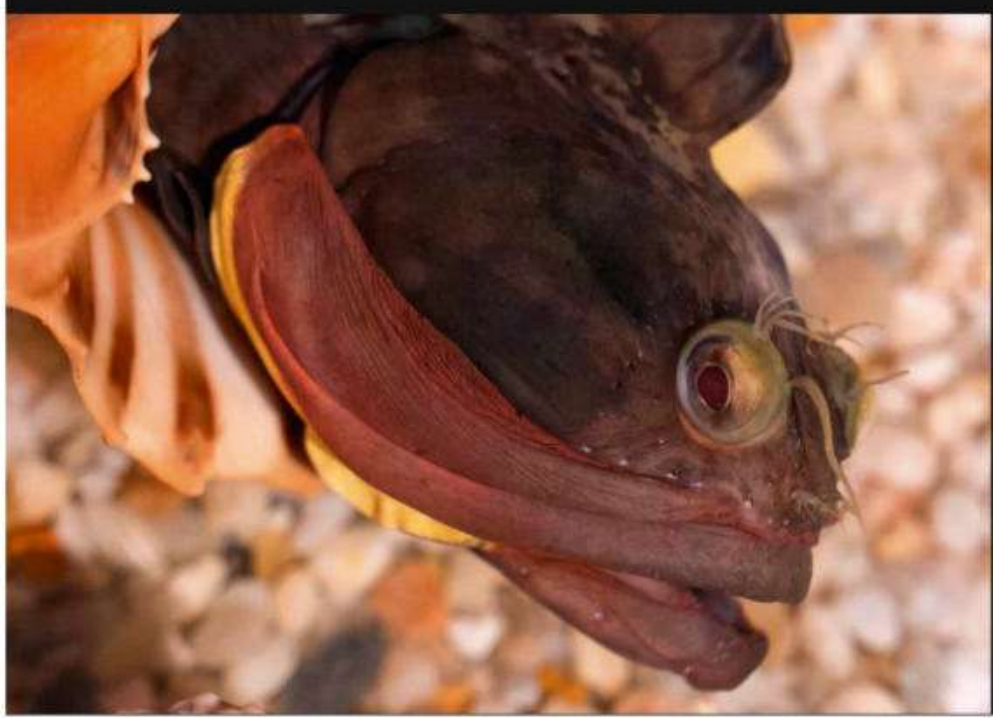
SARCASTIC FRINGEHEAD

It has an awesome name, with an attitude to match. The sarcastic fringehead is a big-mouthed, bolshy blenny that lives in the temperate coastal waters of California and Mexico's Baja California.

These strange fish hang out in their ocean floor dens, which can be burrows, empty shells or even discarded plastic bottles. Males reverse in, bottom first, then defend their territories from other sarcastic fringeheads by dropping caustic one-liners. Only joking! Riled individuals actually face-off by slamming their huge, open mouths together. Laterally-splayed jawbones and sail-like cheek membranes reveal a purple tongue, a double row of teeth, and a fluorescent yellow mouth rim. They look part fish, part Demogorgon from *Stranger Things*.

It's basically a 'who's got the biggest mouth' competition, where the victor bags the best den and a chance to mate. After the female lays thousands of eggs in the prized location and the male has fertilised them, he then defends his offspring with yet more oral aggro.

The name 'fringehead' refers to the floppy fronds of tissue that fall over the fish's eyes, while the term 'sarcastic' is thought either to describe the animal's sardonic closed-mouth expression, or to derive from the Greek word *sarkázein*, which means 'to tear flesh'. Either way, the only thing that's cutting about this fish is its set of teeth. ***HP***



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TOP TEN

WORLD'S MOST PRODUCTIVE COUNTRIES

Are you a serial procrastinator? If so, you'll be please to know that when data scientists measure labour productivity, they don't look at the time you spend scrolling through Twitter. What's measured instead is the average amount of GDP (gross domestic product) a worker creates per hour. That might seem a bit vague if you're a teacher or a taxi driver, but if you work in a factory, just think of it as a measure of how many products you make in an hour.

1. Ireland	**70.09**£/h
2. Norway	**57.15**£/h
3. Switzerland	**48.97**£/h
4. Luxembourg	**48.33**£/h
5. Germany	**47.17**£/h
6. USA	**46.32**£/h
7. Denmark	**45.75**£/h
8. France	**44.40**£/h
9. The Netherlands	**43.43**£/h
10. Belgium	**42.18**£/h

ASTRONOMY FOR BEGINNERS

HOW CAN I SEE CYGNUS?

SEPTEMBER-NOVEMBER

September ushers in the autumn equinox mid-month, heralding the onset of rapidly darkening skies. It provides optimum viewing of the constellation Cygnus, which from dusk appears directly overhead in the night sky.

Cygnus is the 16th largest constellation and is easily recognisable for its distinctive cross pattern that resembles a swan in diving flight.

It sits in the plane of the Milky Way and is rich with sky objects. These include two open star clusters, M29 and M39, which are both easily seen with a decent pair of binoculars.

Even without optical equipment, Cygnus offers some bright stars that are visible to the naked eye. The brightest is Deneb, a blue-white supergiant located around 1,400 light-years away. You may already be familiar with Deneb as it also forms part of another asterism, the Summer Triangle.

At dusk, Cygnus is directly overhead in the southeastern sky and gradually moves towards the west as the night progresses. You can use Vega, one of the brightest stars in the summer sky, to help you find the constellation. Draw an imaginary diagonal line up from Vega to arrive at Deneb, the 'tail' of the swan.

Move along from Deneb and you'll spot the second brightest star in the constellation, Sadr, which is the 'chest' of the swan. Keep following the line down, you'll reach Eta Cygni in the 'neck' and finally Albireo, the 'beak' of the swan.

To the naked eye, Albireo looks like a single star, but binoculars will reveal it as two.

Going back to Sadr, you can easily trace the wings on either side, completing the main stars that make the well-known Northern Cross asterism. ***NB***

Birds evolved from dinosaurs like *Deinonychus*

HOLLY CROSS, CARDIFF

WERE THE DINOSAURS COLD-BLOODED?

If you read many older dinosaur books, you will see *T. rex* and *Brontosaurus* portrayed as ponderous beasts that resemble overgrown lizards or crocodiles. It was once thought that dinosaurs had the same cold-blooded (ectothermic) metabolism as reptiles. In other words, they could not control their body temperatures internally, and so relied on their environment to heat themselves up. And because of this, they grew and moved slowly.

However, in the late 1960s and 1970s, palaeontologists started to doubt this stereotype. The discovery of feisty, svelte bird-like species such as *Deinonychus* revealed that some dinosaurs were faster, smarter, more agile, more energetic and faster-growing than once assumed. Leading experts of this generation, such as John Ostrom and Robert Bakker, argued that dinosaurs were warm-blooded (endothermic), with the same physiology as today's birds and mammals. Dinosaurs, they posited, could finely control their body temperatures, and keep them constant and high, regardless of their environment.

Over the past four decades, palaeontologists have continued to debate this question. It is now widely accepted that dinosaurs were indeed more energetic, with elevated metabolisms and growth rates, compared to reptiles. But did they achieve this through proper warm-bloodedness, or through another mechanism? There remains no definitive answer.

We must remember that nature is not black and white. Animals are not always strictly cold-blooded or warm-blooded. There are intermediates, and one new hypothesis is that dinosaurs were 'mesotherms': they had some control of their body temperatures, but not exact precision, and many species were able to passively keep themselves warm through their enormous bulk. With that said, we know today's birds are warm-blooded, and birds evolved from dinosaurs like *Deinonychus*, so at some point during the dinosaur-bird evolutionary transition, a dinosaur must have become warm-blooded. But when, and how? These are the big mysteries that need solving. ***SB***

WHY DOES THIS OPTICAL ILLUSION MESS WITH MY BRAIN?

The information supplied to our retinas via the photons that get through our pupils is surprisingly sparse. It's mostly a murky blur. The visual processing region of our brain is where the real

JAMES EDGELL, OXFORD

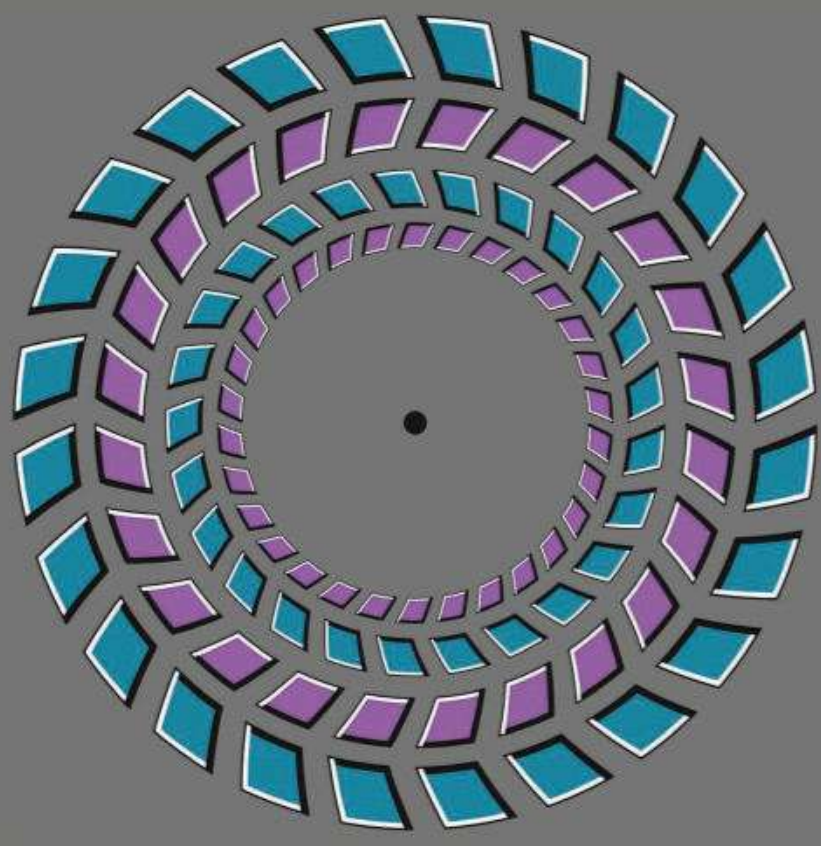
HAS AN OBJECT EVER LEFT EARTH'S ATMOSPHERE THROUGH NATURAL MEANS?

There are at least 277 pieces of Martian rock that have been found on Earth. But, so far, only one possible piece of Earth has been found in space. Inside a lunar sample returned by the Apollo 14 astronauts, scientists found a 2g fragment of quartz, feldspar, and zircon. These are all common minerals on Earth but highly unusual on the Moon. It's possible that the rock formed on Earth about four billion years ago and was launched into space by an impacting asteroid or comet. But we can't be sure – recent research suggests the rock may have a lunar origin after all! ***AGu***

The lunar sample 'Big Bertha' contains a fragment that may have Earth origins

work is done, where the coarse raw data supplied by our eyes is converted into the complex sense of sight. Essentially, our brains are constantly and frantically editing everything that hits our retinas, to make it presentable.

Impressive as it is, this system isn't perfect. Converting the crude retinal information to complex visual perception is an elaborate process and it takes time. That's why we get things like the Pinna illusion (pictured), where complex rings of edged squares appear to be rotating in opposite directions if you stare into the centre of the image and move your head forward, or back.



Exactly why this happens was unknown for quite some time, but a recent study appears to have worked it out. In a nutshell, our brains have multiple systems for recognising and processing visible motion, but the one that recognises, and rules out, illusory motion takes 15 milliseconds longer to have an effect than the processes that say, "looks like motion to me, so that's what we'll see".

It may not sound like much, but 15 milliseconds is a long time at the neurophysiological level. It's certainly long enough for us to 'see' motion in the Pinna illusion, thanks to our less-discerning but faster motion-sensing parts of our brain. ***DB***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

WHY ARE SEEDS SUCH DIFFERENT SIZES?

Think of seeds as like the escape pods we might build for our future offspring. If a global catastrophe threatened humanity, we might try to send thousands of smaller space arks to the Moon or Mars. But if the whole Solar System was doomed and we had to reach another star, the best strategy would be to pin all our hopes on a smaller number of brave astronauts in much larger spaceships.

Plants do something very similar. They have evolved seeds with just enough of a protective coat, packed with just enough food supplies, to keep the embryo alive for the time it takes to reach a suitable environment. Coconuts are the largest seeds (the double coconut can weigh 42kg) and can still germinate after four waterlogged months at sea. Dandelions can produce much smaller seeds because they never need to go far to find a patch of suitable soil. Orchids have the smallest seeds of all (less than a millionth of a gram each) because the chance of finding a suitable spot on a tree branch is very low, so they need to produce millions of seeds at a time.

Once they germinate, the seed also needs to grow enough leaves to be able to survive independently. Plants that live in shady conditions, such as oak trees, produce relatively large seeds because the seedling must grow taller to reach the light. Evolution must balance many other trade-offs too, however. For example, large seeds are also more attractive to predators. Kangaroo rats in deserts tend to eat the largest seeds, so natural selection in those environments favours smaller seeds that are not worth bothering with. ***LV***

GETTY IMAGES, ALAMY, NASA ILLUSTRATION: DANIEL BRIGHT

DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I'M A MONSTER! WHY DO I KEEP HAVING RANDOM VIOLENT THOUGHTS IN PUBLIC?

Everyone has inappropriate, alarming thoughts that occur to them out of nowhere. Thoughts of violence, of sex, of both. Many people worry that such thoughts mean there's something wrong with them. But the opposite is true; they actually mean your brain is working normally.

Human brains don't just learn about the world by observing, experiencing and remembering things that happen to us. They also speculate, anticipate and simulate actions and outcomes. Our brains are constantly churning out thoughts about hypotheticals and 'what ifs' regarding our decisions and actions, to give us the best possible chance of succeeding with whatever it is we're doing. Most of these will be straightforward, uninteresting, and forgotten quickly. These are 'mundane' thoughts. But if your brain is trying to account for every possible option, then logically some of these options will be unpleasant, by dint of having violent, sexual, or other less acceptable qualities.

This is just how the brain works, though. It's a part of who we are. But so is *not acting on them*. Such thoughts are believed to be the subconscious brain's way of checking where the boundaries are. That we experience alarm and distress at the very idea of violence is an important part of the process. ***DB***

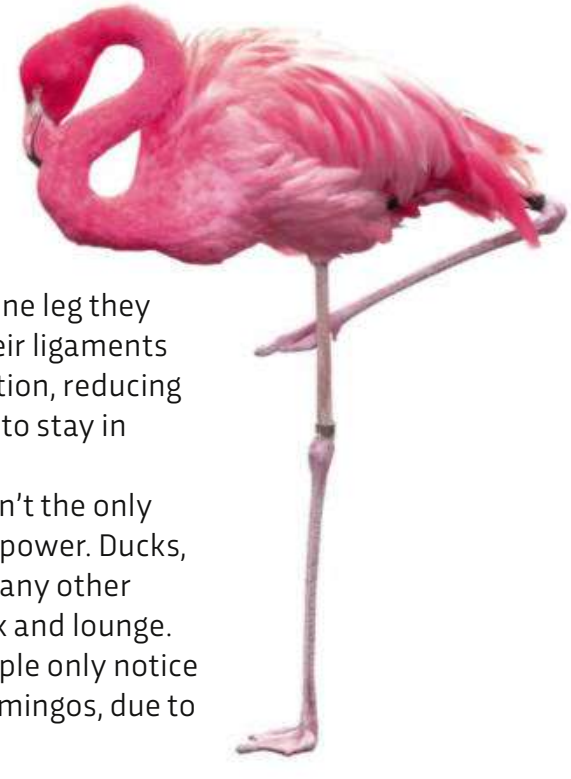
ASHLEY WARREN, CHESTER

WHAT'S THE CARBON FOOTPRINT OF STREAMING TV?

Exact figures can be hard to calculate, but The Carbon Trust – an initiative from University of Bristol researchers, using data from media companies including the BBC, ITV, Netflix and Sky – has calculated that one hour of online video streaming creates carbon emissions of 56 grams of CO_2 equivalent per device per hour. This means that if you spent two hours a day streaming like the average person, you'd create emissions of almost 41kg of CO_2 equivalent per year. ***KB***

FRANCESCA LEWIS, DURHAM

WHY DO FLAMINGOS STAND ON ONE LEG?



Sadly, it's not because they're doing yoga. The fuchsia-feathered birds adopt this stance for several hours each day in order to save energy. How? When standing on one leg they can actually lock their ligaments and tendons in position, reducing any muscular effort to stay in one place.

But flamingos aren't the only birds who have this power. Ducks, geese, swans and many other species can also lock and lounge. However, many people only notice this behaviour in flamingos, due to their long legs.

LAUREN BARRETT, ISLE OF WIGHT

WHY IS FLASH PHOTOGRAPHY BANNED FROM MOST MUSEUMS?

Museums generally cite concerns that camera flashes can damage the pigments in paintings. Some pigments are indeed sensitive to light, which speeds up chemical reactions that break them down. As a result, the lighting in museums and galleries is carefully controlled to minimise damage. But modern camera phones are unlikely to cause additional damage and there is no direct evidence that they do. From a museum's perspective, stopping to take photos will block the flow of visitors and reduce their need to hit the gift shop to buy postcards and prints. Some experts argue that any damage done by camera flashes could be offset by closing and turning off the lights a few minutes earlier each day. ***ED***

QUESTION OF THE MONTH

SAM CONEY, ST HELENS

WHY CAN OLD DREAMS FEEL LIKE REAL MEMORIES?

For some people, old dreams can feel like real memories and this experience is referred to as 'dream reality confusion'. In two studies by researchers from Maastricht University in the Netherlands, difficulty distinguishing dreaming and reality was reported by a substantial minority of participants (12 per cent in one study and 26 per cent in another). It has been proposed by other teams of researchers that the experience is particularly common in certain participants (such as those with narcolepsy or borderline personality disorder).

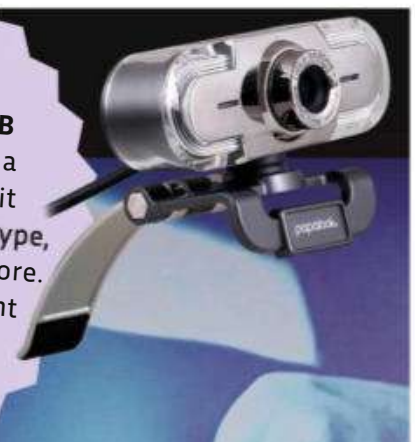
Although there is relatively little research in this area, there are many hypotheses as to why this might occur. One possibility is that the dreams that are confused with reality are different from other dreams (they could be more vivid, for example). It is also possible that when dream reality confusion occurs, this could represent unusual memory encoding during sleep (essentially, there is something unusual about the way in which the dream is converted during sleep, before it is stored in long-term memory).

So, how can you tell if you've experienced dream reality confusion? Simply reading this article could help: becoming aware that false memories can develop could have an impact. As one 2021 study found, merely explaining to participants that their recollections could have been based on something other than reality was enough to correct a false memory – while not affecting their ability to remember true events.

Of course, you can also play detective and consider the evidence. If you think that you swam in Lake Constance with a friend but wonder whether it was in fact a dream, you might want to check whether your friend remembers the experience or whether there are any photos or diary entries from the time to confirm that your fun day at the lake really happened. ***AGr***

WINNER

Sam wins a **Papalook Pro USB webcam**, worth £99.99. With a built-in noise-cancelling mic, it operates in high-definition in Skype, Zoom, FaceTime, YouTube and more. Simple to use and with low-light correction, it's ideal for work and social calls.
papalook.com



WINNER

Next month's winner receives a **MyFirst Camera Insta 2**, worth £93.50. This 12-megapixel instant camera comes with front and selfie cameras, plus it uses thermal printing tech so you never need to refill with ink. Designed for kids, but fun for adults too.
myfirst.tech

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X2, ALAMY X2 ILLUSTRATION: DAN BRIGHT

THE EXPLAINER

WHAT IS LIGHT?

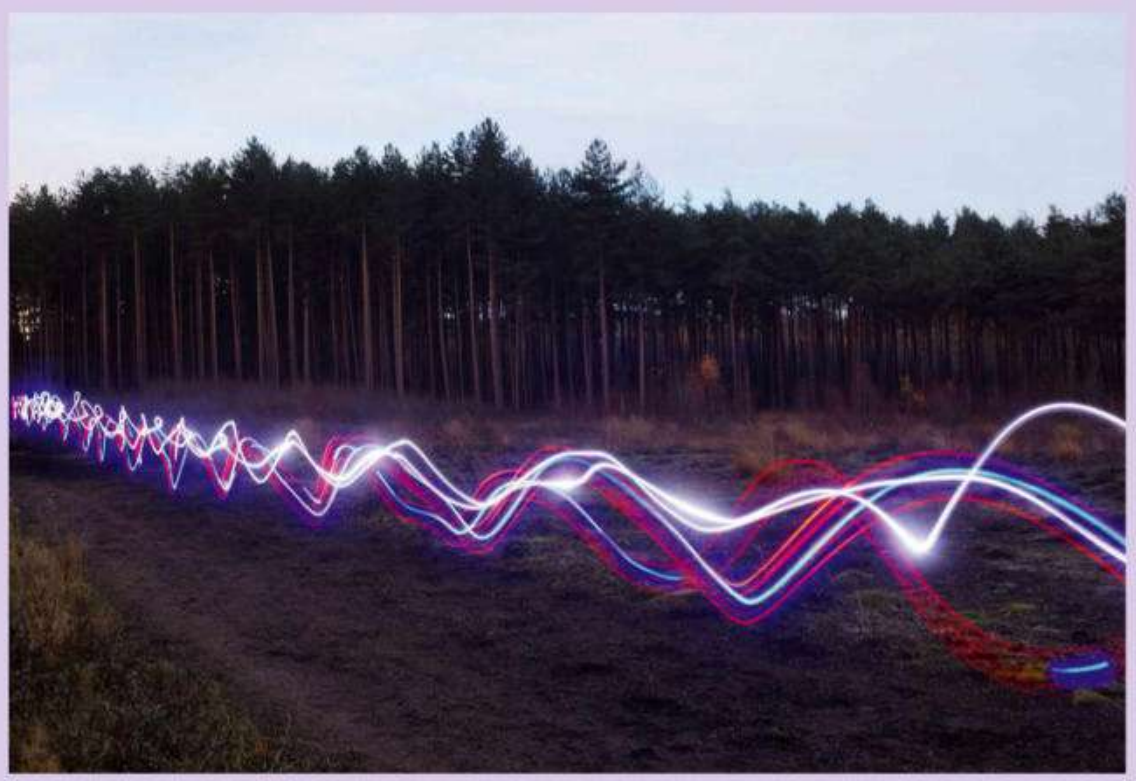
IS LIGHT A WAVE OR A PARTICLE?

Neither: light is its own unique phenomenon – the outcome of an interaction between electrical and magnetic fields – and it behaves like both waves *and* particles.

Most of us were taught at school that light is a wave. This is because it does things that waves do. So, for example, waves undergo interference. To understand this, imagine that you've just dropped two stones in a still pond. Each of those stones will create ripples, with the water creating waves that move up and down. Eventually ripples originating from each stone will hit each other, and the waves travelling in the same direction at that point (up and down, rather than the same direction across the water) will become stronger – this means if a wave peaking upwards hits another wave peaking upwards, it will grow stronger. Equally, those waves travelling in opposite vertical directions could cancel out each other's movement. This is interference – and the same thing happens with light.

However, the quantum revolution of the 20th Century made it clear that light also behaves as if it were a stream of particles. Einstein realised that this was necessary for the photoelectric effect – the mechanism behind solar cells – to work. And our entire understanding of the interaction of light and matter requires light to act like particles known as photons.

Perhaps the easiest way to think of light is as a stream of particles, but quantum particles, which are unlike ones that we can see. And all quantum particles, whether they are photons, or matter particles such as electrons, have wave-like behaviour.



WHAT IS THE SPEED OF LIGHT?

For many years the speed of light was measured more and more accurately, but now we know *exactly* how fast it is – 299,792,458 metres per second.

Hummingbird wings can flap 4,200 times a minute. This sounds fast, but in the time of one invisibly fast flap, light can cross the Atlantic. The quickest that a human has ever travelled (on Apollo 10) was 11,094 metres per second, just 0.0037 per cent of the speed of light. Light speed is the ultimate limit: Einstein's Theory of Special Relativity tells us that it is physically impossible to accelerate past the speed of light.

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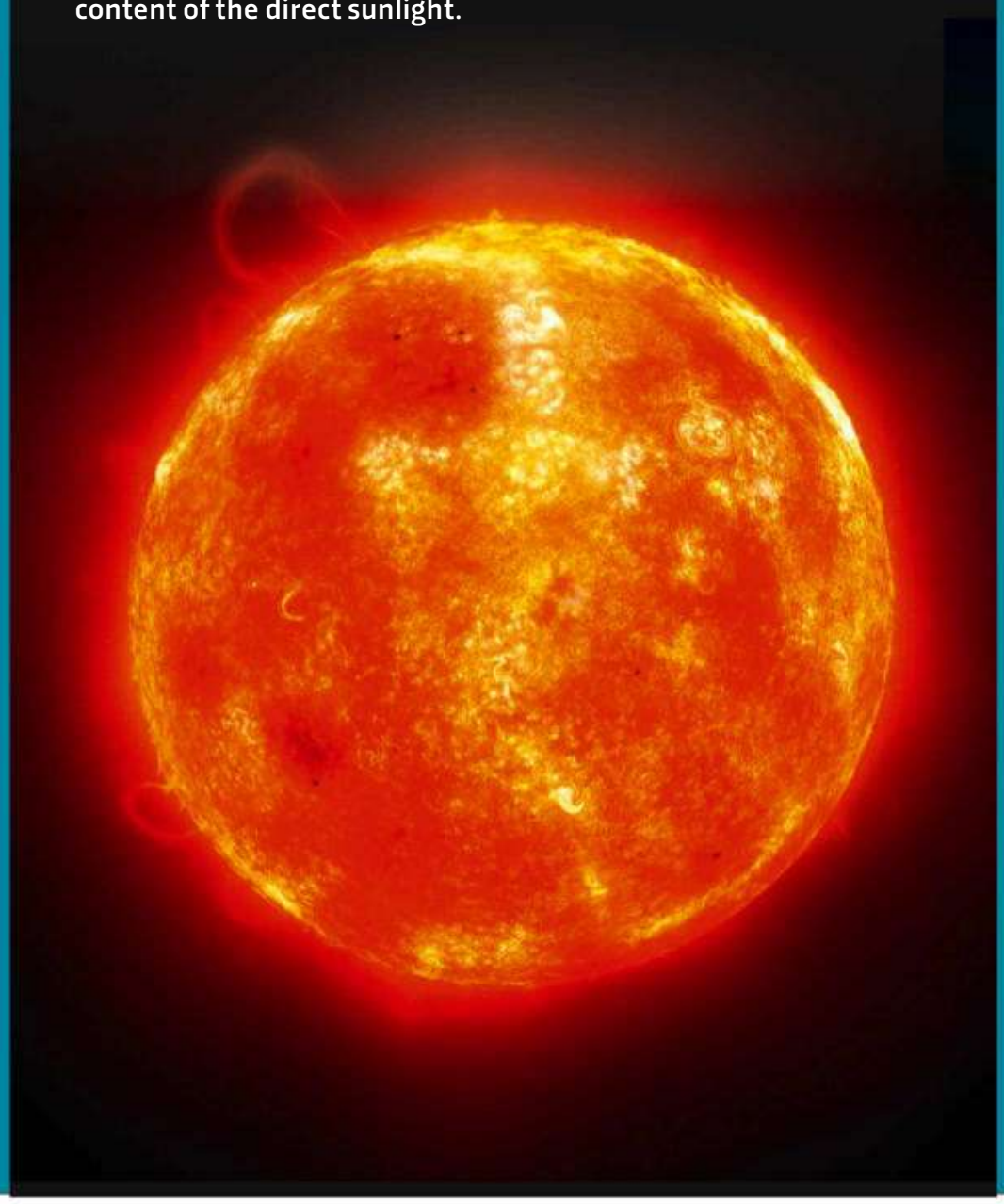
HOW DOES LIGHT CREATE COLOUR?

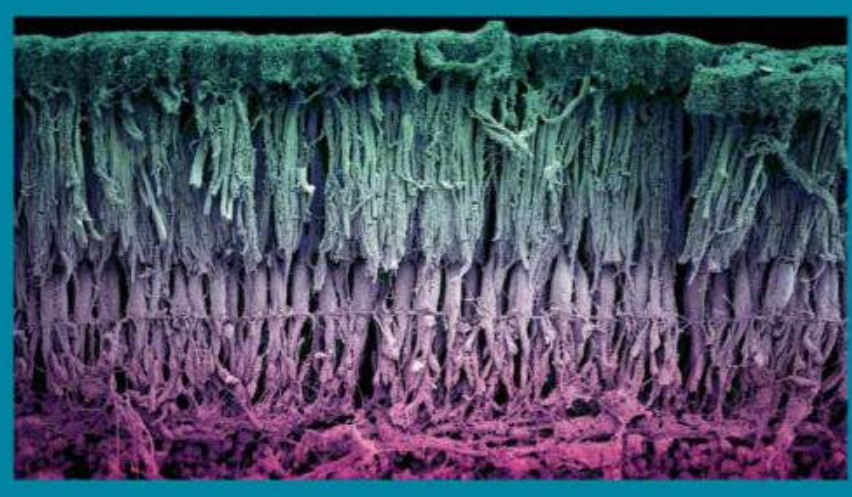
When light hits an object, that object absorbs the light, but then re-emits some of it (called reflection, though the light doesn't bounce off like a ball). The photon energies in the re-emitted light determines the colour of the object. So, for example, a red object re-emits relatively low-energy red photons. The structure of the atoms making up the object determines how far electrons can drop in energy and so the colours produced. But sometimes, such as with feathers, colours are created by refraction, which is also how rainbows occur. Here, photons with different energies travel in different directions, splitting the colours.

HOW IS LIGHT CREATED?

Light is produced when an electron in an atom drops to a lower energy level, releasing the energy as a photon. Quantum physics tells us that atomic electrons can only have certain fixed levels of energy, so that when an electron drops to a lower level it will emit a predictable amount or 'quantum' of energy. The further the electron drops, the higher the energy of the photon.

The light given off by the Sun has a mix of energies making it look white, though it can appear yellow or even red as the Earth's atmosphere scatters blue photons, reducing the blue content of the direct sunlight.





WHY CAN'T HUMANS SEE ALL LIGHT?

The light that we see is just a small part of the electromagnetic spectrum, which stretches from radio through to X-rays and gamma rays. A fundamental property of photons is the amount of energy they carry, corresponding to the wavelength of the light (the distance for a wave to return to the same position in its cycle). For visible light, we call this the light's colour.

No means of detecting light can 'see' the entire spectrum. You can't pick up X-rays with a radio receiver, for instance. However, some animal eyes can cope with energies a little lower than humans can see – the longer wavelength infrared light – while others pick up the slightly higher energy ultraviolet light with its shorter wavelength. This can be useful because many flowers have ultraviolet patterns visible to pollinating insects, while hawks can detect small mammals in the grass far below them just from the ultraviolet glow of urine trails.

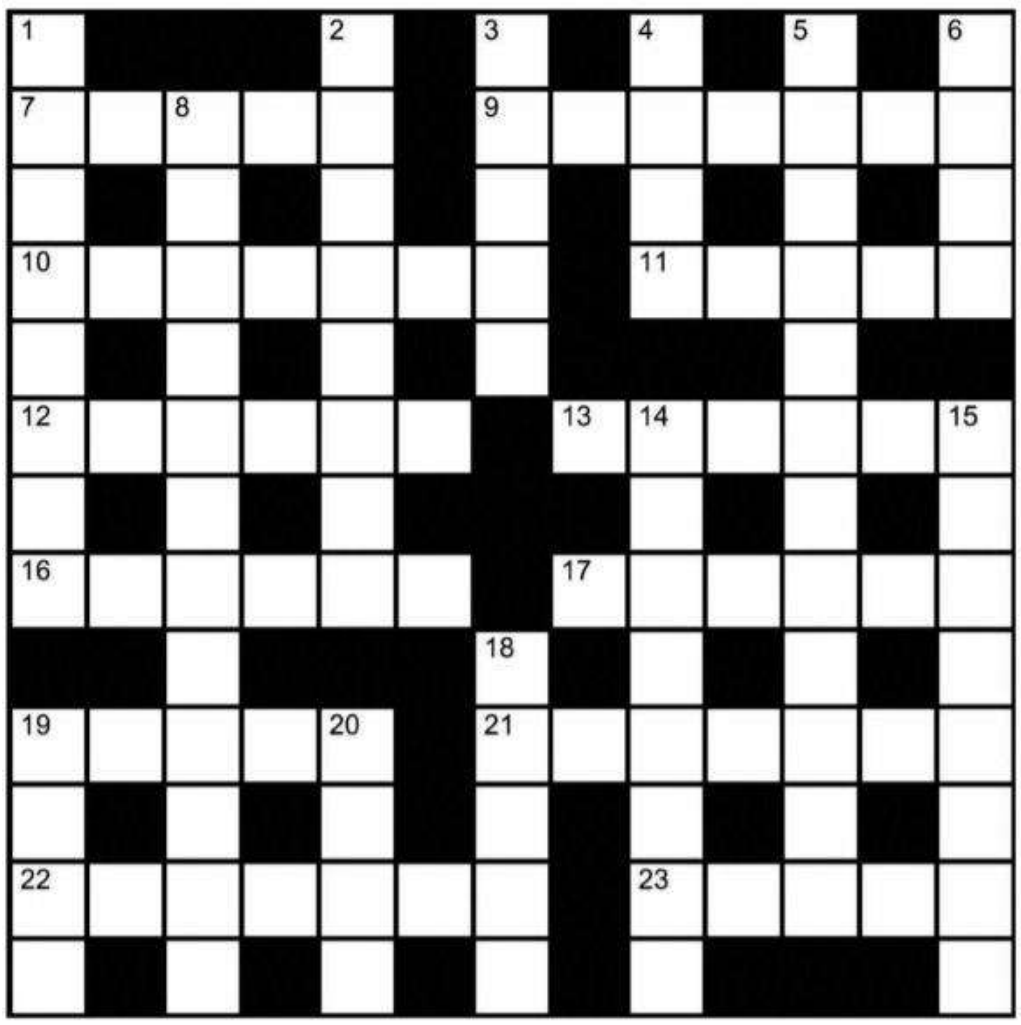
The precise colours our eyes detect depend on light-sensitive cells known as cones. We have three types of these that are most sensitive to colours around blue, green and yellow/red. The hawks seeing ultraviolet have a fourth cone type, while many mammals only have two kinds of cone, as their eyes are dominated by colour-insensitive rod cells, essential for night vision. This is because mammals were originally nocturnal. Primates like humans appear to have gained the extra cone type around 35 million years ago – our colour range, it is suggested, was particularly suited to finding fruit.

by **BRIAN CLEGG**

Brian is a science writer and author of Light Years: The Extraordinary Story Of Mankind's Fascination With Light *(£8.99, Icon Books).*

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

7 Policemen point to some trees (5)
9 Unfair treatment when buying salad ingredients? (3,4)
10 Straighten a French religious sign (7)
11 Fat Greek character takes cover out (5)
12 Deceive first threesome by way of petty details (6)
13 Strong drink for morale (6)
16 Car test includes gag about bait (6)
17 Blamed criminal for causing scene of confusion (6)
19 Gem held between rubbery lips (5)
21 Baffle complete, wife missing burrow (7)
22 Expert note about being solvent (7)
23 Scandinavian food (5)

DOWN

1 Get used to a cold habit (8)
2 Nice and poor, cooking cheese (8)
3 Search for loud hazard (5)
4 Initially, and not properly, missing (4)
5 Recreate label, promote brainy bit (8,4)
6 Walk like a policeman (4)
8 Hierarchy among hens? (7,5)
14 Rep's exit managed to be earlier (3-5)
15 Moderated mood with journalist (8)
18 Following many for dessert (5)
19 Stop getting round a wild animal (4)
20 Money left - too weird (4)

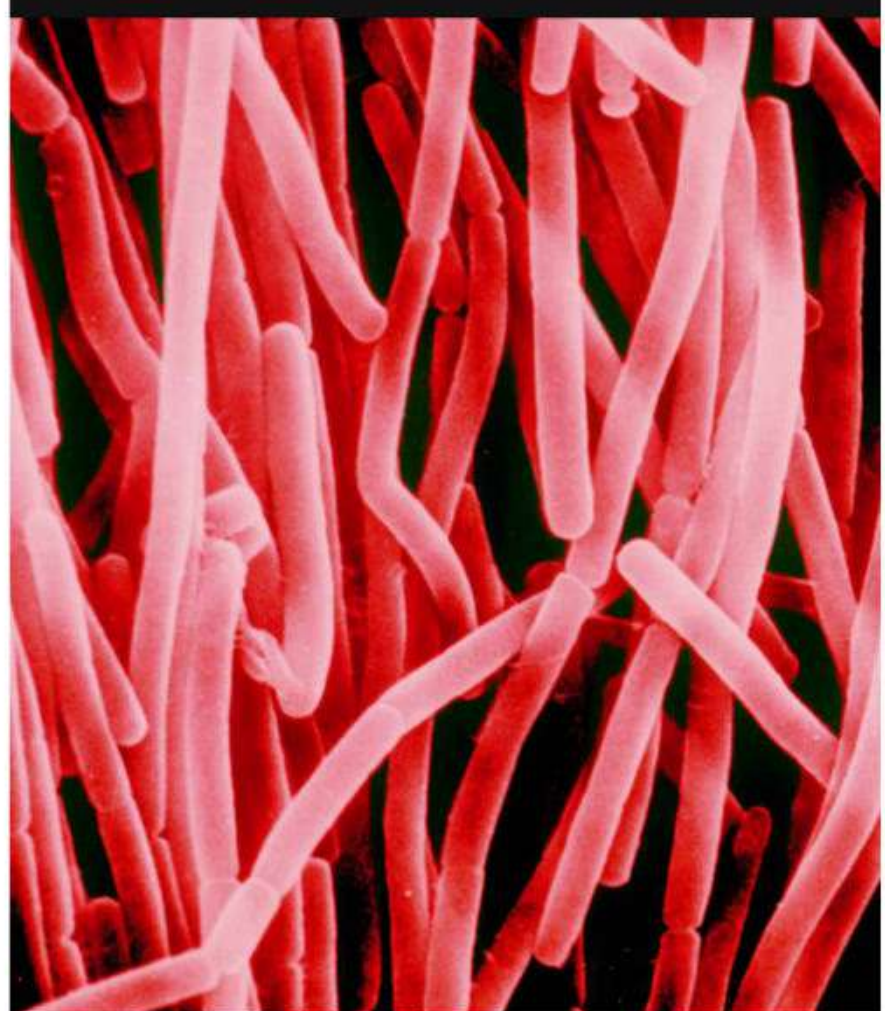
ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

GIVE YOUR HOME A PROBIOTIC MAKEOVER



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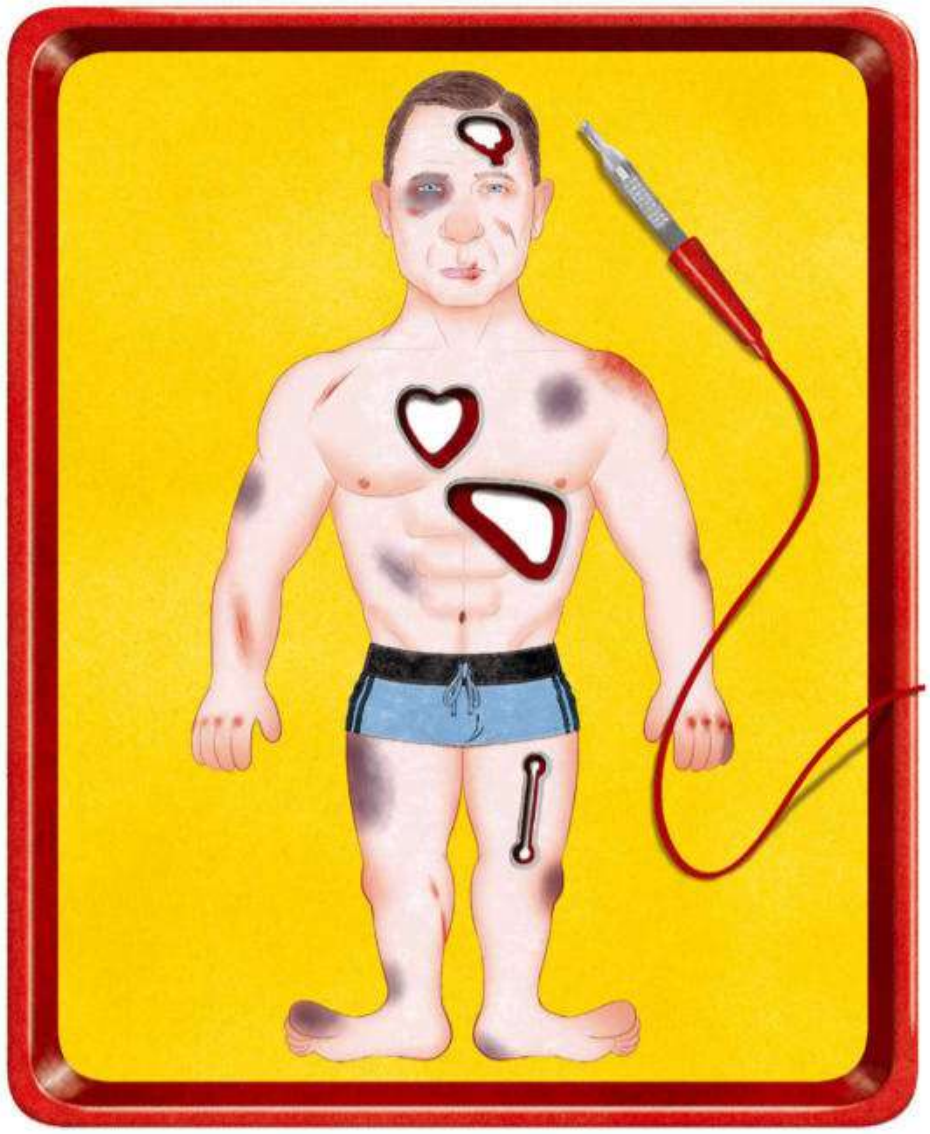
POPCORN SCIENCE

How broken is James Bond's body?

Would 007 pass a physical ahead of new movie *No Time To Die*?

by STEPHEN KELLY

After 25 movies in 59 years, it's time for James Bond to make an appointment with a doctor. After all, surely a lifetime of dodging bullets, fighting villains, jumping off buildings and regularly drinking more cocktails than a Blackpool hen night cannot be good for you? We asked Carl Heneghan – a GP and professor of evidence-based medicine at the University of Oxford – to sit Bond down for his check-up.



THE NAME'S INJURY, HEAD INJURY

James Bond has been knocked unconscious from hits to the head 14 times throughout his career. "These are serious head traumas that will affect brain function," says Heneghan. "In the long term we're talking chronic traumatic encephalopathy, a neurodegenerative disease that plagues contact sports like American football." Symptoms could include early onset dementia, anxiety, depression and impaired judgment. "You could say, in terms of the films, some of those are already there. Especially the impulse control problems."

SHAKEN, ALSO SLURRED

In a study published in 2018 by *The Medical Journal Of Australia*, it was calculated that over the course of 24 movies Bond was observed drinking 109 times, averaging 4.5 drinks per movie. "Long-term alcohol consumption will eventually lead to a process called fatty liver disease, and eventually cirrhosis," says Heneghan.

STI ANOTHER DAY

Over the course of 25 films, James Bond has slept with around 57 women. This isn't a problem within itself, of course. But when was the last time you saw Bond pause a romantic scene to sort out, ahem, protection? "His risks are going through the roof in terms of sexually transmitted diseases like gonorrhoea or chlamydia," says Heneghan. "In the long term, Bond may have problems with sterility and inflammatory disease, and if left untreated that inflammation could give him a heightened risk of cancer."

BULLETS GALORE

During his time in the field, Bond has dodged at least 4,662 bullets. However, he was hit in *Skyfall*, where he is shot first in the shoulder, then in the chest and sent plummeting to a river far below. "If a bullet misses all the major organs and arteries, you can survive it," says Heneghan. But I would say it would take at least a year to get back to normal afterwards."

HEARTBREAKER

One of *Casino Royale*'s most punishing scenes sees Bond poisoned by digitalis, which can give you a cardiac arrest. But not to worry: thanks to a prompt defibrillation, Her Majesty's finest spy is resurrected – and returns to a high-stakes poker game minutes later. "It's implausible but not impossible that would resuscitate him and he would recover," says Heneghan. "But the damage to his heart would have been significant. It would take a long time to strengthen his heart muscle, which does not recover like other muscles in the body." SF

SALTY

VERDICT

The Dr says no: burdened with a lifetime of critical injuries, Bond is in far from killer shape.

by STEPHEN KELLY (@StephenPKelly)
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATIONS: ADAM GALE MAIN ILLUSTRATION: JASON RAISH

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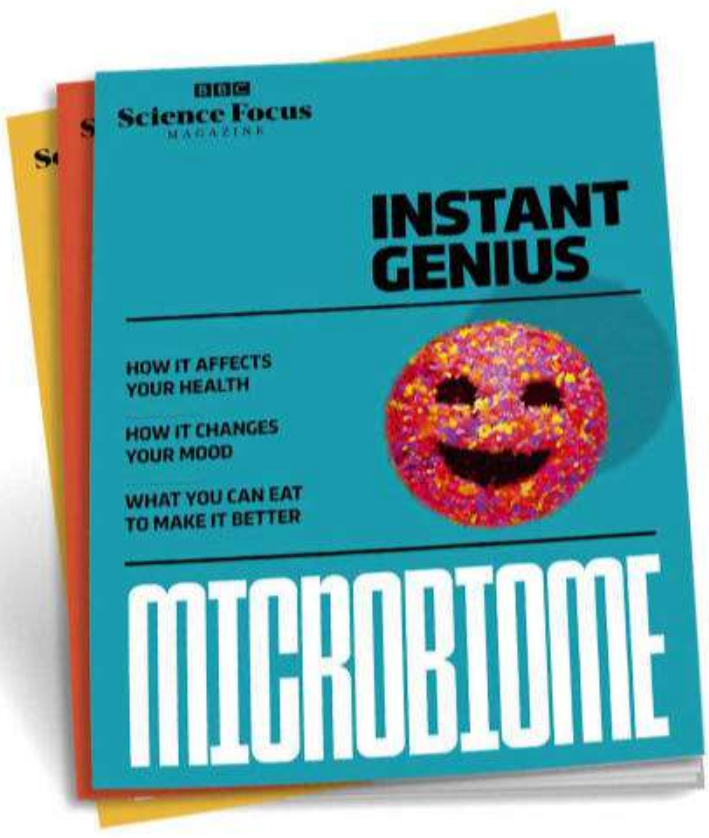

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